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THESIS

USING OPTIMIZATION TO IMPROVE TEST PLANNING

by

Arlene M. Payne

September 2017

Thesis Advisor: Jeffrey E. Kline
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Test schedule development is a specialized process that is complex, time-consuming, and iterative. For Department of Defense program management offices, test schedules play a critical role in program schedule development and decision making. This research captures a Department of Defense program management office's existing test scheduling process that is developed based on heuristics. This research establishes requirements for conversion of the test scheduling process into a test scheduling optimization model that is constraint and rule-based. The developed model is verified and validated to assess whether it is functioning as intended and to determine if the test scheduling optimization model can be used to aid test planners in their test planning schedule development efforts. The results of this research indicate that, with additional work to make the input more user-friendly and to display the output differently, the test and evaluation test schedule optimization model would be a good tool for the test and evaluation schedulers.

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USING OPTIMIZATION TO IMPROVE TEST PLANNING

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ABSTRACT

Test schedule development is a specialized process that is complex, time-consuming, and iterative. For Department of Defense program management offices, test schedules play a critical role in program schedule development and decision making. This research captures a Department of Defense program management office's existing test scheduling process that is developed based on heuristics. This research establishes requirements for conversion of the test scheduling process into a test scheduling optimization model that is constraint and rule-based. The developed model is verified and validated to assess whether it is functioning as intended and to determine if the test scheduling optimization model can be used to aid test planners in their test planning schedule development efforts. The results of this research indicate that, with additional work to make the input more user-friendly and to display the output differently, the test and evaluation test schedule optimization model would be a good tool for the test and evaluation schedulers.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAV	assault amphibious vehicle
ACAT	acquisition category
AoA	analysis of alternatives
APA	additional performance attribute
ATC	Aberdeen Test Center
AVTB	Amphibious Vehicle Test Branch
BBP	better buying power
C4I	command, control, communications, computers, and intelligence
C	communications
CA	California
CJCSI	Chairman of the Joint Chiefs of Staff instruction
COA	course of action
COCOM	combatant command
COI	critical operational issue
Comm	communications
CTP	critical technical parameter
DAG	Defense acquisition guide
DAU	Defense Acquisition University
DOD	Department of Defense
DODAF	DOD architecture framework
DODD	Department of Defense directive
DODI	Department of Defense instruction
DPG	Dugway Proving Ground
DT	developmental testing
E3	electromagnetic environmental effects
EPG	Engineering Proving Ground
EVA	extravehicular activity planning

F	firepower
FOC	full operational capability
GAMS	general algebraic modeling system
IDEF0	integrated computer aided manufacturing definition for function modeling
IOC	initial operational capability
JCIDS	joint capabilitites and development system
KPP	key performance parameter
KSA	key system attribute
LF	live fire
LM	land mobility
MDA	milestone decision authority
MOS	military operational skills
MS	Microsoft
MSG	marine security guards
NASA	National Aeronautics and Space Administration
NBC	nuclear, biological, and chemical
NR	net ready
OA	operational assessment
OE	operational effectiveness
OS	operational suitability
OSD	Office of the Secretary of Defense
OT	operational testing
OTA	operational test agency
PERT	Program Evaluation and Review Technique
PM AAA	Program Manager Advanced Amphibious Assault
PMO	program management office
PPBE	planning, programming, budgeting and execution
RF	radio frequency
ROS	rapid obscuration system

RSCSP	resource constrained scheduling program
RFP	request for proposal
S	survivability
S/HF	safety/human factors
Surv	survivability
TE	test and evaluation
TA	test asset
TEMP	test and evaluation master plan
USD (AT&L)	Undersecretary of Defense for Acquisition Technology and Logistics
USD (C)	Under Secretary of Defense (Comptroller)
YPG	Yuma Proving Ground
WM	water mobility
WSMR	White Sands Missile Range

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EXECUTIVE SUMMARY

Test schedule development is a specialized process that is complex, time-consuming, and iterative. For Department of Defense program management offices, test schedules play a critical role in program schedule development and decision making. This research captures a Department of Defense program management office's existing test scheduling process that is developed based on heuristics. This research establishes requirements for conversion of the test scheduling process into a test scheduling optimization model that is constraint and rule-based.

The initial problem formulation is generated in conjunction with Dr. Gerald Brown, NPS Distinguished Professor of Operations Research. Operational needs are developed based on the test scheduling process and based on the problem formulation. An analysis of alternatives is performed against existing optimization models using the operational needs. Detailed requirements are generated based on the critical operational issues, based on the operational needs, and based on the problem formulation.

Another thesis student, Shane A Edwards, (Edwards 2015) finalizes the problem formulation in conjunction with Dr. Brown, develops the optimization model, and performs his own developmental optimization model testing.

The final model run provided by Shane Edwards is reformatted into 3-dimensional daily test schedules for the five different test schedules generated by the model. The model input files, output files, and reformatted 3-dimensional daily schedules are used to verify conformance to the detailed requirements.

The 3-dimensional daily test schedules are aggregated into 3-dimensional monthly test schedules. The reformatted optimization model-provided monthly 3-dimensional schedules are assessed against the test and evaluation heuristic 3-dimensional schedules. Assessment results are validated against the operational

needs, the critical operational issues, and for operational effectiveness and suitability.

Results show that the optimization model developed by Shane Edwards (Edwards 2015) meets the majority of the requirements and provides schedules that are reasonably close to what the test and evaluation planners would use. The results of this research indicate that, with additional work to make the input more user-friendly and to display the output differently, the test and evaluation test schedule optimization model would be a good tool for the test and evaluation schedulers.

Reference

Edwards, Shane A. 2015. "Optimizing Department of Defense Acquisition Development Test and Evaluation Scheduling." Masters thesis, Naval Postgraduate School.

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I. INTRODUCTION

Test schedule development is a specialized process that is complex, time-consuming, and iterative. For Department of Defense (DOD) program management offices (PMOs), test schedules play a critical role in program schedule development and decision making. This research captures a DOD PMO's existing test scheduling process that is developed based on heuristics. This research establishes requirements for conversion of the test scheduling process into a test scheduling optimization model that is constraint and rule-based. The developed model is verified and validated to assess whether it is functioning as intended against the requirements and to assess the model against heuristic schedules. The purpose of this research is to determine if the test scheduling optimization model can be used to aid test planners in their test planning schedule development efforts.

Stakeholders in this research are DOD PMOs and, specifically, test personnel supporting DOD PMOs. Potential interest could include developmental and operational test agencies, and contractors who need to perform test planning activities.

To understand what influences defense system acquisition test scheduling, a basic appreciation is needed of DOD organizational relationships and of DOD processes. Department of Defense processes of significance include budgeting, system acquisition, and requirements development and verification processes. Providing information in these areas provides context for PMO test scheduling activities and promotes understanding of the many interdependencies.

A. ORGANIZATIONS AS SYSTEMS

Department of Defense system acquisition is performed by systems command organizations within each of the services. These systems command organizations exist to acquire needed warfighter capabilities in the form of

systems. The ultimate goal of the systems acquisition community is to acquire systems that will ensure warfighters achieve their mission objectives. Program management offices within systems commands are the organizations that perform the system acquisition work.

As Anderson and Johnson discuss, organizations are themselves systems (1997, 2). This organizational system thinking is synopsized in Figure 1 and is applicable to systems commands.

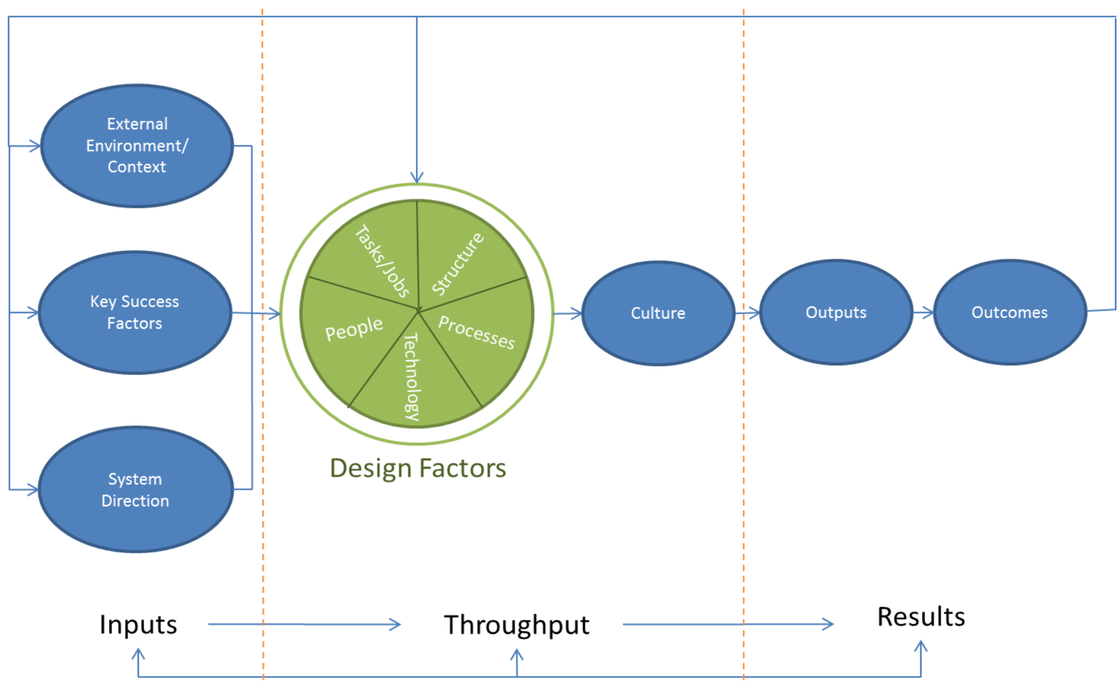

Figure 1. Organizational Systems Framework

Figure 1 and the associated discussion is adapted from class notes and lectures and is based on data provided by the NPS instructor Cary Simon (Nancy C. Roberts, class notes provided by Cary Simon based on slide generated by Roberts in 2000, class notes and lectures provided to author, September 12, 2012). Figure 1 depicts organizations as systems with internal and external dependencies. The organization itself is impacted by external environment, by its context within that environment, by key success factors, and by organizational

direction, which are all considered input. External environments to an organization are political, economic, social, and technological. Key success factors indicate what it will take for the organization to be successful. System direction is influenced by mission, values, mandates, strategic issues, vision, goals, and strategies. The organization itself has internal components that impact the performance of the organization, shown as "throughput." These internal components are people, tasks/jobs, structure, processes, technology, and culture. Results of the organization consist of outputs and outcomes. Outputs are what the organization delivers such as goods and services. Outputs can be measured in terms of performance relative to the key success factors. Outcomes can be intended or unintended, and are the consequences of the outputs viewed in context with the external environment.

Program management offices can be considered organizational systems and can be looked at from this organizational systems framework viewpoint, with inputs, outputs, and outcomes. Understanding a PMO as an organization with external and internal dependencies furthers understanding of the impacts of these dependencies on test schedules.

B. DOD DECISION SUPPORT SYSTEMS TRIAD

As shown in Figure 1, to perform system acquisitions, the people in a PMO organization must perform tasks that will result in the intended outcome. The tasks performed are bound by the external environment of an imposed set of DOD acquisition processes. As described by Defense Acquisition University (DAU) (2017b), for a DOD PMO, these external decision support processes, also known as the Big "A," are the DOD decision support systems triad of: the planning, programming, budgeting and execution (PPBE) process, the joint capabilities and development system (JCIDS) process, and the defense acquisition system process. As described on DAU's defense acquisition portal, the "[Department of Defense] has three principal decision-making support systems. Together, the systems provide an integrated approach to strategic planning, capabilities needs

assessment, systems acquisition, and program and budget development" (DAU 2017b). These three processes are symbiotic, as shown in Figure 2.

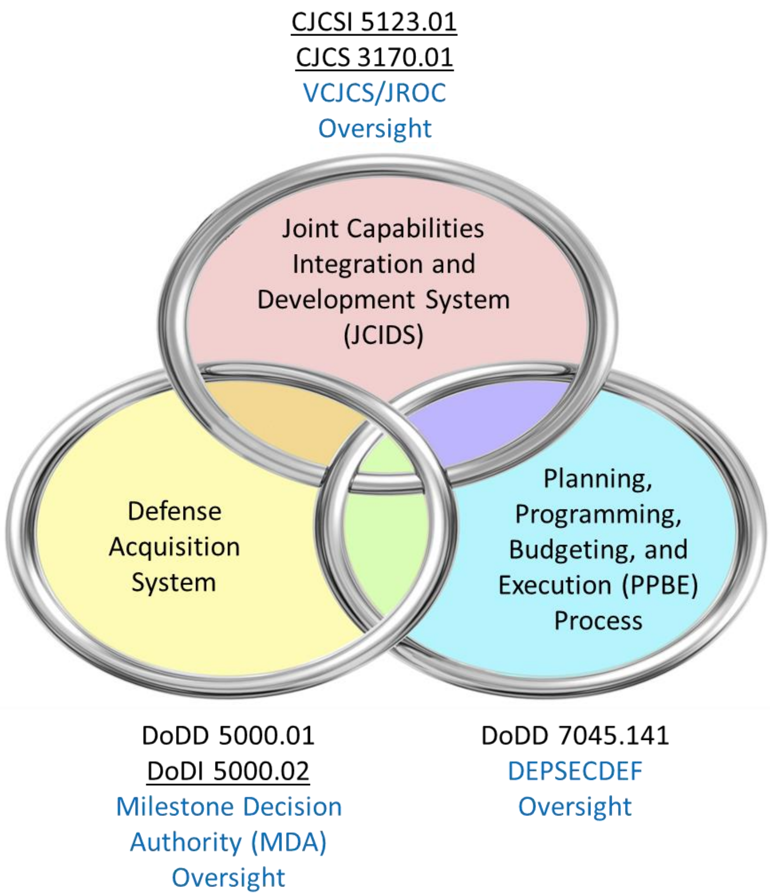

Figure 2. DOD Decision Support Systems Triad. Source: DAU (2017a).

Using the Anderson and Johnson method of relationship depiction (1997, 2), the DOD decision support systems triad and the triad stakeholders are imposed upon the PMO, as shown in Figure 3.

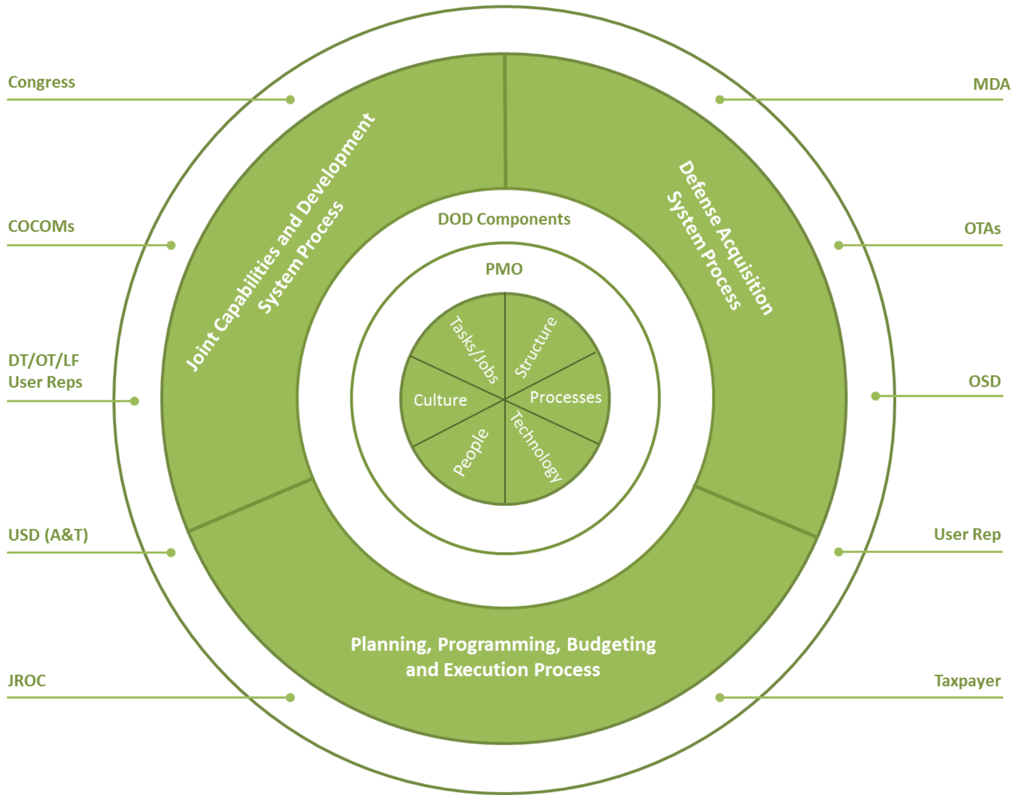

Figure 3. Inter-relationships and Intra-relationships between Stakeholders, the DOD Decision Support Systems Triad, and the PMO

Department of Defense components are defined by the Undersecretary of Defense for Acquisition Technology and Logistics (USD (AT&L)) as “[Office of the Secretary of Defense], the Military Departments, the Office of the Chairman of the Joint Chiefs of Staff and the Joint Staff, the Combatant Commands, the Office of the Inspector General of the Department of Defense, the Defense Agencies, the DOD Field Activities, and all other organizational entities within the DOD” (USD (AT&L) 2017, 1).

Taking the concept provided in Figure 1, we expand upon this in Figure 3, adding in information from Figure 2, showing the specifics of the PMO within the DOD triad. This relationship diagram shows that, in addition to the many internal organizational inter-relationships, there are many external stakeholders who will influence the resulting system acquisition strategy, including the three symbiotic

and intertwined process triad. The external success factors of the systems acquisition strategy include political, economic, social, technological, mission, values, mandates, strategic issues, visions, goals, and strategies.

1. Planning, Programming, Budgeting and Execution Process

The PPBE process is a fiscal year calendar-based process that is used to plan, budget, and execute a DOD acquisition program (DAU 2017c). Details of the PPBE process are contained in Department of Defense directive (DODD) 7045.14. As explained in this Under Secretary of Defense (Comptroller) (USD (C) 2013) directive, the PPBE process is used to identify resource requirements, allocate resources, produce a five-year programming plan, and budget and execute a yearly budget. PPBE results must align with the needs identified in the national security strategy, while being constrained by resources allocated by Congress (USD (C) 2013, 2).

2. Joint Capabilities and Development System Process

The JCIDS process is a strategic, calendar-based, and event-based process that assesses strategic needs in conjunction with critical needs identified through the PPBE process due to real world events. Details of the JCIDS process are contained in Chairman of the Joint Chiefs of Staff instruction (CJCSI) 3170.01 (CJCS 2015b) and in the supporting JCIDS manual (CJCS 2015c). What follows in this paragraph is a high level explanation of JCIDS activities discussed in these CJCS documents. The JCIDS process identifies DOD gaps that need to be filled (CJCS 2015a, A-1). Before a new or modified system is proposed, the JCIDS process explores changing Doctrine, Organization, Training, Materiel, Leadership and education, Personnel, and Facilities (DOTMLPF) (CJCS, 2015b, 2). If a need is deemed to be a priority, an analysis of alternatives (AoA) is conducted to determine whether an existing system can be modified to meet the need or a new system is needed (USD (AT&L) 2017, 18). The output of the JCIDS process is a capability document that provides warfighter requirements for system modification or for a new systems acquisition

(CJCS 2015b, 2). The capability document is provided to the systems command PMO for systems acquisition execution.

3. Defense Acquisition Process

The defense acquisition process is an event-based process that guides program managers and DOD components through milestones, decision points, and phases for the lifecycle of a system's acquisition, sustainment, and disposal. DODD 5000.01 (USD (AT&L)) 2003) and Department of Defense instruction (DODI) 5000.02 (USD (AT&L)) 2017) provide details of defense acquisition policy, process, and procedures. Systems are given acquisition category (ACAT) levels that indicate required documentation and activities (USD (AT&L)) 2017, 3).

Upon determination that there will be a system modification or new system acquisition based on the JCIDS process, the program manager and the supporting PMO personnel then start the arduous task of working through the defense acquisition process. The PMO formulates a program and develops the required systems acquisition documentation in support of the acquisition approach (USD (AT&L) 2017, 7).

C. SYSTEMS ACQUISITION PROGRAM STRUCTURE

As shown by the information provided, the DOD decision support systems triad is event driven and calendar driven, which further complicates PMO activities since the PMO must balance and support all three processes. The management framework, within which a systems acquisition program exists, is called the systems acquisition program structure (DODI 2000.02 2017, 6).

The systems acquisition program structure guides the PMO by providing a general approach to systems acquisition in the form of phases and events as shown in Figure 4 (DODI 2000.02 2017, 9).

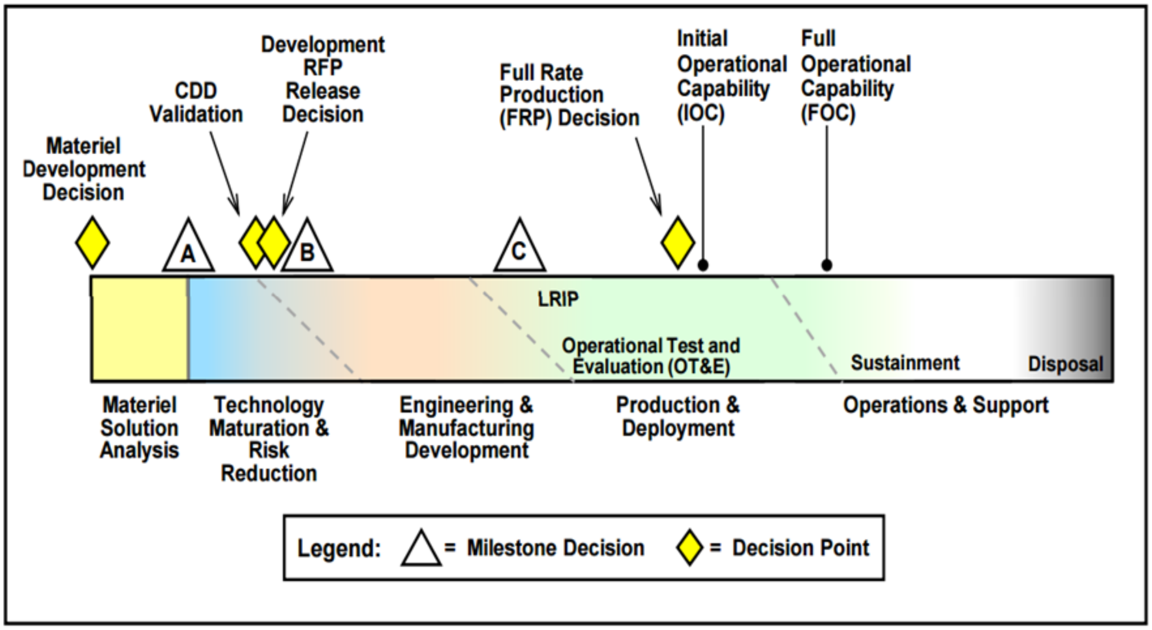

Figure 4. System Acquisition Program Structure (Hardware Dominant). Source: DODI 5000.02 (2017).

Figure 4 shows a systems acquisition program structure for a hardware dominant system (DODI 5000.02 2017, 9). What follows in this section is an explanation of Figure 4 based on the DOD instruction. The systems acquisition program structure identifies five phases that a system may go through (material solution analysis, technology maturation and risk reduction, engineering and manufacturing development, production and deployment, and operations and support). A system can enter this program structure at any of the three milestones (A, B, or C), depending on the maturity of the technology used in the system and depending on the maturity of the system itself (USD (AT&L) 2017, 6). This means that a highly mature system may enter the defense acquisition program structure at milestone B and only go through three phases: engineering and manufacturing development, production and deployment, and operations and support. A system goes through many decision points to assess status and to make needed decisions, as indicated by a yellow diamonds (USD (AT&L) 2017, 6). The milestone triangles at the top of Figure 4 are also decision points.

DODI 5000.02 (2015) provides variations of this program structure based on aspects of particular programs that may require different focus, such as acquisition of software intensive systems, accelerated acquisition systems, and hardware dominant systems. The Figure 4 diagram is for a hardware dominant system (DODI 5000.02 2015, 9). The intent of providing many options in this instruction is to move away from a one-size-fits-all checklist mentality in the acquisition community and to give program managers the flexibility to provide a cost and schedule optimized solution as described in better buying power (BBP) 3.0 (USD (AT&L) 2015). The seven BBP 3.0 (USD (AT&L) 2015) principles are: achieve affordable programs, control costs throughout the product life cycle, incentivize productivity and innovation in industry and government, eliminate unproductive processes and bureaucracy, promote effective competition, improve tradecraft in acquisition of services, and improve the professionalism of the total acquisition workforce.

Flexibility in approach to the systems acquisition program structure is highlighted by the dotted lines between the acquisition phases and the color variations in Figure 4, as this is a significant departure from prior versions of this program structure that contained solid lines and colors. As stated in the instruction, “[Milestone decision authorities] should tailor regulatory procedures in the document consistent with sound business practice and the risks associated with the product being acquired” (DODI 5000.02 2015, 2).

To support the DOD decision support systems triad, the PMO must perform many scheduling activities. Although PMO schedules have similarities, all PMO schedules are unique. As the PMO performs planning and decision making activities, they assess different courses of action (COAs). The PMO varies program entry points, milestones, numbers of systems to be delivered in each phase, delivery schedules, test events, and test schedules. The PMO puts together an achievable, cost-constrained, best-value plan for acquisition of the system. The chosen schedule is then incorporated into the acquisition

documentation, including the test and evaluation master plan (TEMP) (USD (AT&L) 2017, 106).

As the PMO progresses through execution of their plan, and as internal and external events change, the PMO constantly reassesses the schedule and performs course corrections. This means that the schedule is in constant scrutiny, and that schedule and cost COAs are in constant development throughout the systems acquisition and sustainment life cycle.

D. SYSTEMS ENGINEERING PROCESS

As explained by DAU (2014), the systems engineering process is an internal DOD organizational process that provides the technical framework within the DOD systems acquisition program structure to guide the PMO during systems acquisition. What follows in this section is an explanation of the DOD DAU systems engineering process. Within the PMO, the systems engineer is responsible for the definition and for the execution of the specific systems engineering aspects of the PMO acquisition plan and strategy. While each systems acquisition is different, the systems engineering process remains the same, although complexity, technical reviews, timeframes, and responsible parties may vary. The DAU defines the systems engineering process in the form of a “V,” as is shown in Figure 5 (DAU 2014). The Figure 5 systems engineering “V” shows the path from operational need identification to fielding a capability to meet that need.

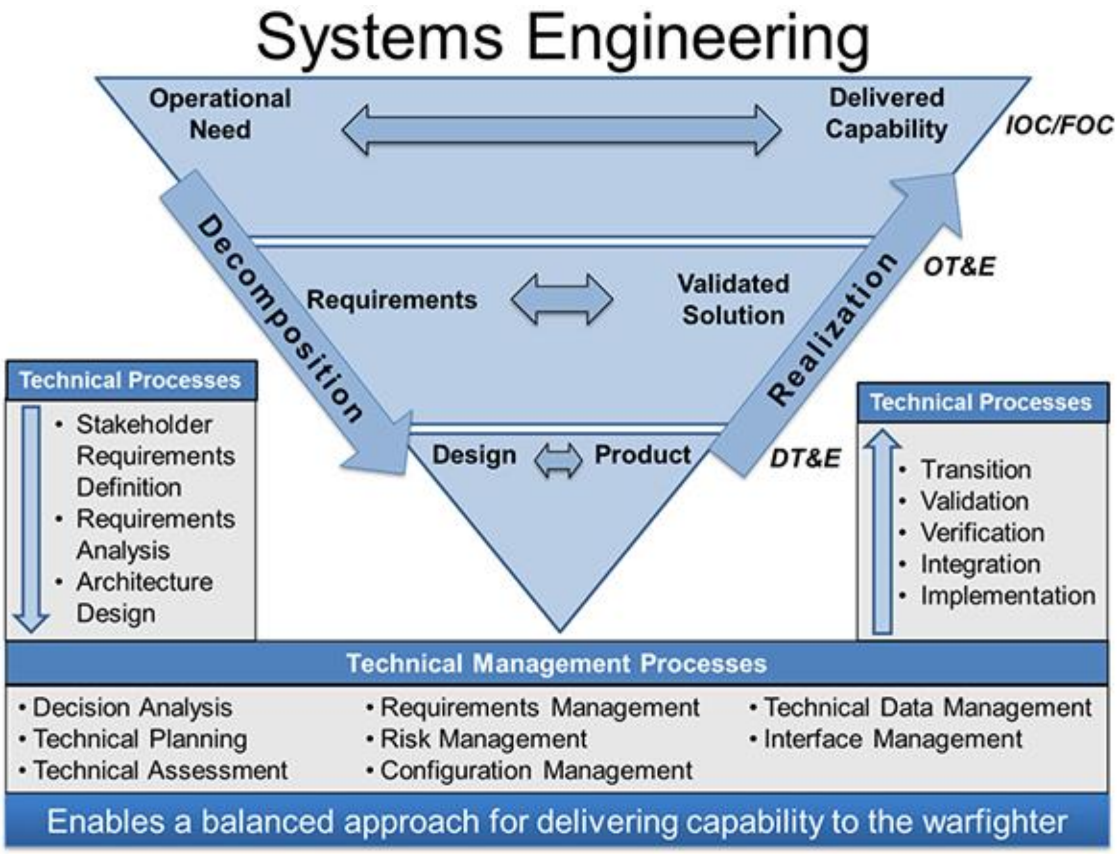

Figure 5. System Engineering Process. Source: DAU (2014).

If there is deemed to be a need for a system capability, and the need is considered to be a priority within the budget, a program is begun within the DOD with the development of the operational need via a capability document (CJCS 2015b, A-10).

The system engineer, in concert with PMO personnel, performs market surveys and requests for information from industry in order to hone in on what is currently available in the marketplace that might meet the need (USD (AT&L) 2017, 88). The systems engineer considers whether an existing system(s) could be modified to meet the need. Simultaneous with these activities, a formal AoA is performed to see if there are existing systems within the DOD that might meet the need and to determine the correct type of system (USD (AT&L) 2017, 19).

The system engineer, in conjunction with PMO personnel, will work through potential alternatives to meet the need.

What follows on the next several pages is a detailed explanation of the flow through the systems engineering “V” diagram provided in Figure 5 (DAU 2014). The systems engineering “V” starts with user capabilities identified by the end user shown as “operational needs.” The JCIDS process results in the capabilities document that starts the systems engineering process. The JCIDS process involves the PMO in order to assess whether the capabilities defined are achievable and to determine the priority of the stakeholder needs (USD (AT&L) 2017, 21). The systems engineer works with the user representative to elicit stakeholder prioritized requirements, taking into account affordability, product and technology availability, and technology readiness levels (USD (AT&L) 2017, 20). The answers to these questions translate into capability and program risk (USD (AT&L) 2017, 19). This technology risk level will guide specifics of the program acquisition plan, contract type, and entry point into the acquisition program structure.

The user representative identifies threshold and objective capabilities in the form of a capability document, which defines operational needs (CJCS 2015c, D-A-1). The capability document is augmented by a mission profile document, which explains how the system operates in the mission environment in peacetime and in wartime (CJCS 2015c, B-24). The capability document is further augmented by a DOD architecture framework (DODAF) set of views that explain how the system operates within the communications architecture (in support of joint interoperability) and that provide specific details underpinning the net ready key performance parameter (NR KPP) (CJCS 2015c, C-B-1). A KPP within a capability document is deemed to be a high priority capability. The NR KPP is a priority capability that all DOD systems must meet in order to be fielded (CJCS 2015c, D-61). The capability document is updated at program milestones as the systems acquisition proceeds through the systems acquisition program structure.

The systems engineering “V” shown in Figure 5 continues with decomposition of the user capabilities document, mission profile document, and DODAF views into system requirements. Requirements are also incorporated from DOD instructions, directives and regulations. The resulting system performance specification is the document that is provided to the organization that is responsible for the system design (USD (AT&L) 2017, 23). In most cases, the organization that designs the system consists of an outside contractor or contractors.

The PMO develops a request for proposal (RFP) to elicit potential system product developer solutions to the operational needs specified in more detail in the system performance specification. Upon completion of all required systems acquisition documents, upon congressional approval of the program budget, and upon approval by the Secretary of Defense, the RFP is released to potential contractors (USD (AT&L) 2017, 7). RFP responses are evaluated using the source selection process based on source selection criteria. Once the system product developer(s) are selected by the source selection authority, a contract, or contracts, is awarded (USD (AT&L) 2017, 25).

The systems engineering “V” shown in Figure 5 continues with product development. The system product developer(s) proceed through product design and development, and through the systems engineering technical review gates of the systems acquisition process (USD (AT&L) 2017, 26). The system product developer performs system requirements analysis, architecture design, design implementation, system integration, and system test, and delivers the developed system to the PMO (USD (AT&L) 2017, 26).

The TEMP provides a high level coordinated test plan within the approved acquisition plan, acquisition strategy, and overarching program schedule, and is included as one of the required acquisition documents (USD (AT&L) 2017, 4). Developmental testing (DT) and operational testing (OT) test plans are articulated at a high level in the TEMP. The capability document, the mission profile, and the DODAF are used in development of the DT and OT test plans by

the DT and OT community. The TEMP is updated at program milestones within the specific system acquisition program structure and as supported in the acquisition plan and the acquisition strategy.

The systems engineering “V” shown in Figure 5 continues with solution verification and validation. Upon receipt of the system, the PMO performs developmental verification through inspection, demonstration, certification, analysis, and testing. The system performance specification is used to develop the DT program that is used by the PMO to verify that the system meets the system performance specification requirements. The PMO assesses the probability of success in OT and in meeting system capabilities.

Upon completion of PMO DT verification activities, Figure 5’s systems engineering “V” continues with delivery to the operational test community who provide validation against the capability document (USD (AT&L) 2017, 25). The operational test agency (OTA) will assess the system for operational effectiveness, operational suitability and operational security (USD (AT&L) 2017, 104).

Upon successful accomplishment of validation of the capability, Figure 5’s systems engineering “V” concludes with the system proceeding into production and fielding to the warfighter as an initial operational capability (IOC) and ultimately full operational capability (FOC) (USD (AT&L) 2017, 30).

E. DOD PMO TEST PLANNING

Within a DOD PMO, test personnel support the many tasks required. As the PMO performs its initial planning and as potential changes are assessed, test personnel support the development of different COAs in support of schedule and cost activities. During this COA development activity, the PMO varies the number of test assets available, test activities to be performed, and the test time that is available. This COA activity is completed for each phase of the acquisition life cycle where test assets are needed.

Multiple schedule COAs are generated to support different PMO COAs. After the test schedule COAs are developed, the schedules are each evaluated for the cost associated with them. Once the COA is decided upon, the test schedule that supports the decided upon COA becomes the system test schedule. As the program proceeds through its life cycle, there are many COA activities. The schedule is subject to change based on the many internal and external pressures, some of which are shown in Figure 6.

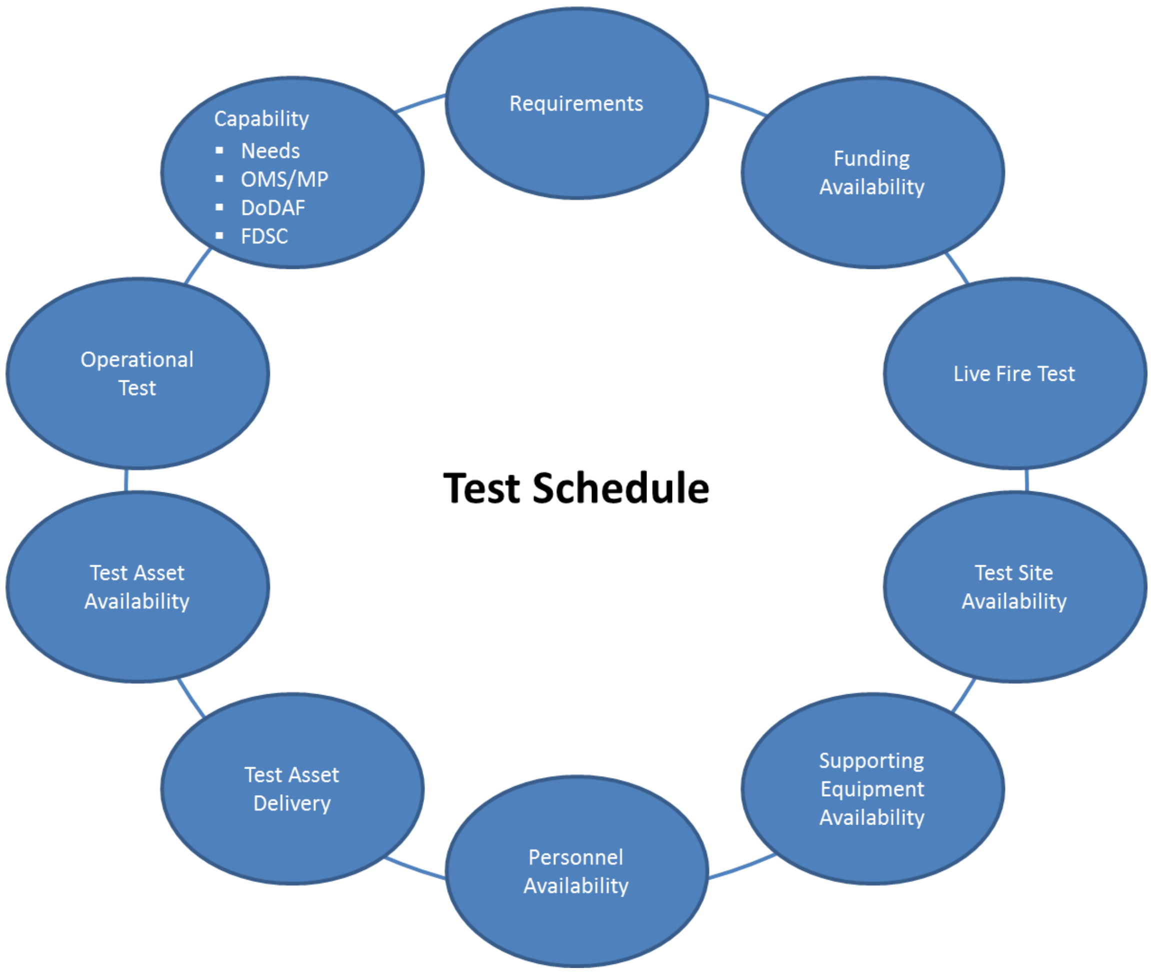

Figure 6. Test Schedule Change Pressures

As can be seen from Figure 6, there are many considerations, limitations, constraints, and challenges in planning and executing a test schedule. In addition

to DT planning, PMO test schedulers must work with other organizations to determine their needs for operational tests and live fire (LF) tests, and plan appropriately within the overarching test and PMO schedule (USD (AT&L) 2017, 90). The LF vehicles become vehicles that are not available for DT testing, and the OT window confines the PMO DT test schedule.

Program management office test schedulers must work with test sites for test site availability, recognizing that the test assets may not be delivered as planned. Test schedulers must arrange for support equipment and spares to support the test activities, and they must assure that test and supporting personnel are available to support each of the tests. PMO test schedulers must estimate funding needs in spite of the potential for change based on possible test changes due to late delivery, adverse weather conditions, retests, and maintenance issues.

Program management office test schedulers must address requirements verification. Test schedulers must provide the PMO with confidence that the system is ready to move into OT by performing test events of an OT nature such as Reliability Growth Testing (RGT). PMO test schedulers must address multiple COAs and must plan for change as a natural course of doing business within a DOD PMO.

Program management offices require a dynamic test schedule and a dynamic test execution process. As system capabilities are changed, these changes may result in system requirements changes, which change test event durations and test events needed (USD (AT&L) 2017, 92). As the PMO test personnel work with other test organizations, OT and LF test event changes may impact the test timing. As funding changes, schedules may need adjustment to assure execution. As the test assets are built, issues may arise in production that may affect the delivery schedule. Test assets may not be available due to maintenance or other issues. Test sites may not be available due to schedule changes or other competing activities and programs. Personnel needed to support test events may not be available as planned on the schedule, and test

events may require certain seasonal weather, which may require shifts in other test events to accommodate timing shifts. Equipment needed for a test event may have issues with availability. These examples are a limited set of the many possible test schedule change pressures as indicated in Figure 6.

F. PROBLEM STATEMENT

This research explores whether optimization can aid in the test schedule development process. The research questions addressed by this thesis are:

- Can a test scheduling model automate the test schedule development process?
- Can a test scheduling model optimize the PMO test scheduling activity to provide multiple optimized test schedule options?
- Can a test scheduling model determine the best PMO schedule mix of test assets and test facilities?

These research questions are similar to the overarching critical operational issues (COIs) that are asked in the TEMP. The resulting model from this research will be evaluated against these COIs using the systems engineering approach identified in Figure 5.

G. ORGANIZATION OF THESIS

This thesis is organized into six chapters, with model input and output contained in Appendix A, and 3-D monthly schedule conversions contained in Appendix B.

Chapter I introduces the thesis by providing background information of DOD processes within which DOD PMOs and their test planners exist, explaining DOD PMO test planning within these processes, and providing the problem statement.

Chapter II promotes understanding of the problem by establishing the test and evaluation (TE) test scheduling process, providing the model problem

statement, identifying operational needs, exploring model alternatives, and explaining model development activities.

Chapter III establishes model requirements through the development of an integrated computer aided manufacturing definition for functional modeling (IDEF0) representation of model requirements, development of model definitions, and creation of detailed requirements based on the IDEF0 representation. Requirements are organized into IDEF0 areas of inputs, outputs, controls and constraints, and mechanisms, resources, and tools.

Chapter IV focuses on verification of the model against the model requirements of Chapter III and continues to reflect the IDEF0 organization.

Chapter IV uses the model inputs and outputs and the TE 3-D schedule conversions contained in Appendix B to assess the model against the requirements.

Chapter V validates the model against the operational needs identified in Chapter II, aggregating the model 3-D schedules showing days in a month to a higher level 3-D schedule showing months in a year. These 3-D model schedules are compared against the 3-D TE planning schedules.

Chapter VI contains the conclusions from this research and potential future work.

II. UNDERSTANDING THE PROBLEM

A. TE TEST SCHEDULING PROCESS

This thesis focuses on the test activities within the Program Manager Advanced Amphibious Assault (PM AAA) vehicle acquisition programs. The PM AAA PMO supports United States Marine Corps (USMC) ship to shore marine transport systems.

Within the PM AAA PMO, PMO test personnel develop test schedules for each COA, per Figure 7. The PM AAA test schedule development process shows the activities that the TE test planners conduct in support of PM AAA schedule and cost development. This test schedule development process is developed in coordination with PM AAA PMO test personnel. Although this process documents the specific process used within the PM AAA, a similar process would be used within other DOD PMOs. The test schedule development process is a result of this thesis research.

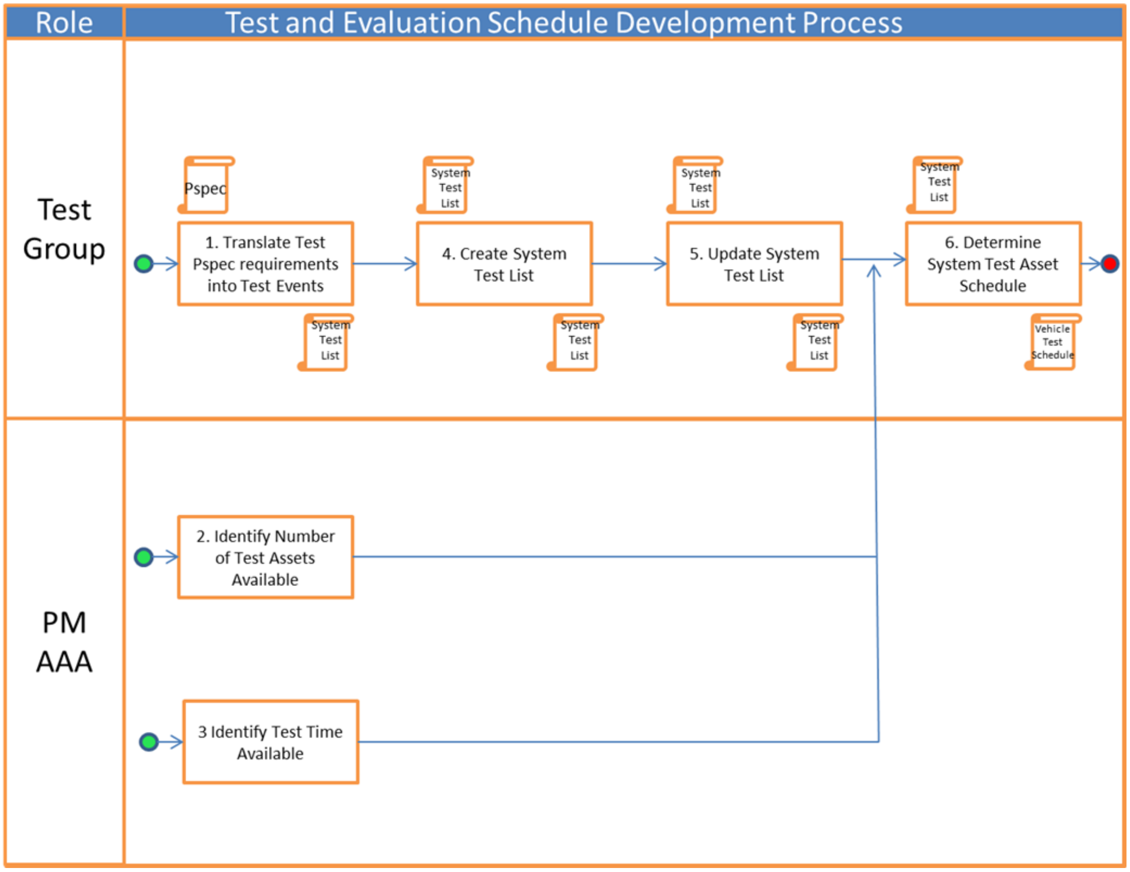

Figure 7. PM AAA Test Schedule Development Process

Details of the Figure 7 test schedule development process steps are provided:

Step 1. Translate System Performance Specification Test Requirements into Test Events. The first step in the test schedule development process is to translate the system performance specification test requirements into test events. During this step, test personnel review the system performance specification test requirements and identify the specific test events that need to be performed. Test events are identified by test asset type since there may be multiple test asset variants. Test personnel also identify the number of days of testing needed for each test event, how many test assets are needed to complete each test event, whether the test requires more than one test asset

simultaneously, and the priority of the test event. Step 1 is performed simultaneously with Step 2 and with Step 3.

Step 2. Identify Number of Test Assets Available. The second step in the test schedule development process is to identify the number of test assets available. During this step, the PMO identifies and provides test personnel with the total number of test assets that are available for testing. The number of test assets available for testing excludes the LF test assets, since LF tests require dedicated test assets. Test assets available are identified for each test asset type. In most cases, there will be multiple COAs that will need to be assessed, which will require going through the process for multiple numbers of test assets. Step 2 is simultaneous with Step 1 and with Step 3.

Step 3. Identify Test Time Available. The third step in the test schedule development process is for the PMO to identify and provide the test time available for test execution. The test personnel translate the overall test schedule time into the total number of time periods available. This involves identifying time periods available for each test asset. The PMO also identifies major schedule events and decision points, which will constrain the test schedule through test event sequencing, through completion times required, and through high, medium and low priority time periods. In most cases, there will be multiple COAs that will need to be assessed, which will require going through the process for multiple test times. Step 3 is simultaneous with Step 1 and with Step 2.

Step 4: Create System Test List. The first step is followed by a review of prior system test lists to identify a system test list that is close to what the new system test list needs to contain. The test personnel then use the selected prior system test list as a starting point and update it to contain the information needed in the new system test list. The test personnel review the system test list for changes based on the activities for step 1 and step 3. Depending on the test events needed, there may be deletions, updates and additions.

Step 5. Update Test List. During this step, test personnel identify test agencies and test facilities that can perform each of the test events and identify the preferential order that they would chose the test agency for each test event. Test personnel identify all test event test sequencing relationships, predecessor test events, and test event priorities (high medium and low). These process activities are performed for each test asset type. Test personnel place test events into test functional groups, called critical technical parameter (CTP) areas, which will be reflected on the higher level published test schedule.

Step 6. Determine System Test Asset Schedule. The last step in the test schedule development process is to determine the system test asset schedule using inputs from the previous steps. The intent of this step is to determine the best system test asset schedule to minimize facility movement of each test asset and to minimize the completion time of all test events while maintaining the constraints of prioritization, sequencing, and completion times. Multiple schedules are produced during this step for each set of test asset numbers and test time periods, resulting in a best case minimum schedule, a worst case maximum test schedule and the most likely test schedule.

Test scheduling is currently performed using Microsoft (MS) Excel through a series of meetings with multiple PMO test personnel. PMO test personnel use heuristics, based on their knowledge and experience, understanding what test events are predecessor and successor tasks, the relative priority of the test events, which test facilities can perform the test events, which test facilities are preferred to perform the test events, how many test assets are needed for the test events, and simultaneous testing test facility bandwidth. Initial test scheduling activity takes weeks to complete.

B. MODEL PROBLEM STATEMENT

Developed in coordination with this research, the following statement is the quoted problem statement from the model developer's thesis and consists of multiple paragraphs:

> There are several variants of test asset (e.g., pieces of a type of equipment to be tested) that need to be subjected to a set of test events conducted at a number of test venues (i.e., test facilities). Each test event may apply to some subset of test asset variants, and may be performed by any suitably equipped test venue.
>
> The planning horizon consists of discrete, ordered time periods (say, days). Each test asset is to be initially delivered to a test venue at the start of a given scheduled time period, but may be subsequently moved among other venues. Completing each test event requires visiting a test venue for some given number of contiguous time periods. Moving a test asset from one test venue to another venue, and inspecting it on receipt, requires a given number of contiguous time periods. A test asset located at a test venue may be held back for other activities, and thus be unavailable for testing during some time periods. A test asset can only undergo a single test event during any time period, and each test event will be conducted at most once during the planning horizon.
>
> Each test event has a priority (an ordered attribute), and all higher-priority test events should be started before any lower-priority ones are started, and completed before a priority-specific deadline day. Lowest-priority tests can be completed at convenience, including past the end of the planning horizon (i.e., these are optional tests).
>
> Some tests have precedence over others, and are required to be completed before the others are started, independent of their priority. All test events of or above a given priority threshold must be completed, and the objective is to minimize completion time of the last of these tests.
>
> Each test venue has a limit on the number of test assets it can accommodate at any time, but there is no limit on test venue capacity to perform simultaneous tests. (Edwards 2015, 15)

This problem can be represented in a three-dimensional space, with the coordinates of time, test facility, and test event, with the test asset variants moving through time, as shown in Figure 8. Solutions are constrained by which test events are needed by variant, by what test facilities can support the test events, by relationships between the test events, by test facilities that can complete the test events, by test event priorities, by priority deadlines, and by overall schedule completion times. Therefore, there is a subset of the entire

space of available solutions that will meet the constraints, and there is an optimized solution or set of solutions to minimize the total test schedule time and to minimize the test asset movement between facilities.

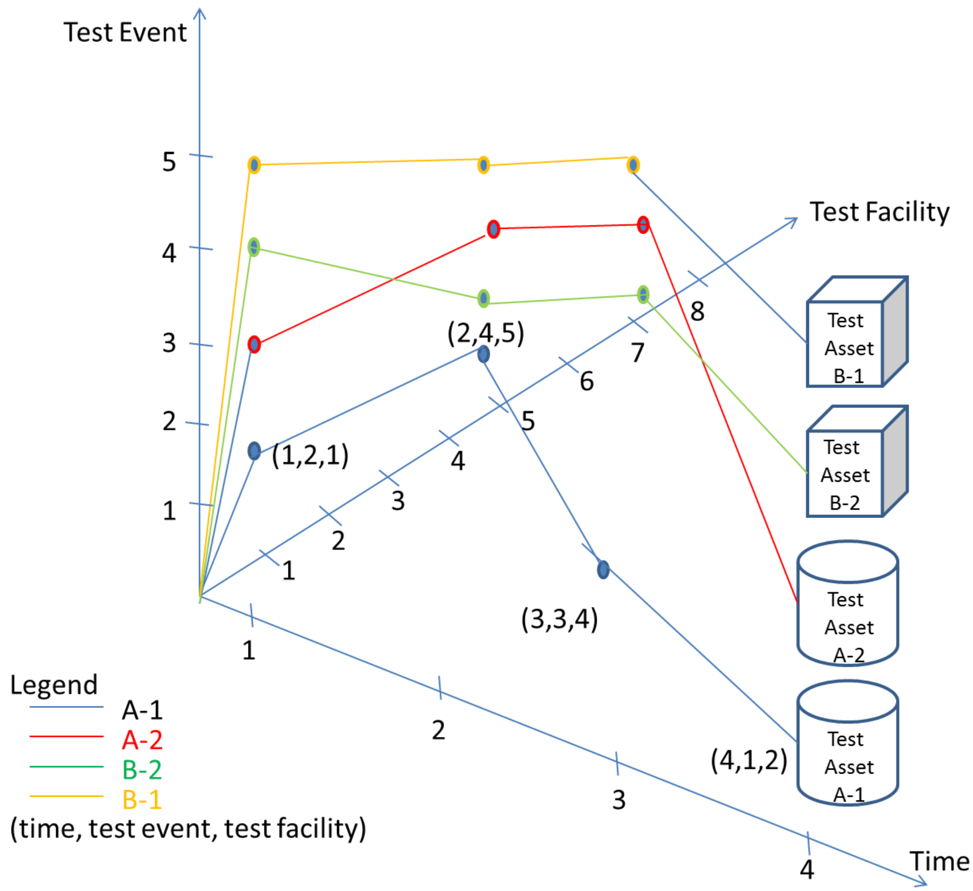

Figure 8. Test Schedule Problem 3-D Representation

Figure 8 is an illustrative example of an optimal solution for four test assets, A-1, A-2, B-1 and B-2. The test assets designated as “A-x” are one variant type, whereas the test assets designated as “B-y” are a different variant type. Each of these test assets move from point zero through the solution space over time through the points, showing the chosen test event at a chosen test facility at a point in time, until the entire set of test events are completed. For example, test asset A-1 (blue) begins time period one starting at test facility 2,

which conducts test event 1. A-1 then moves at time period 2 to test facility 5 to complete test event 4. At time period 3, A-1 moves to test facility 4 to complete test event 3. Finally, A-1 moves to test event 1 at test facility 2 at time period 4. Not every point of the three-dimensional space is available to every test asset. There is a set of points available to each variant set (a set for “A-x”s, and a set for “B-y”s).

C. MODEL OPERATIONAL NEEDS

As illustrated in Figure 5, the first step in the systems engineering “V” is the development of model operational needs, which are given in Table 1.

Table 1. Model Operational Needs

Need #	Title	Tier	Operational Needs
N1	Low Priority Test Events (O)	APA	The model low priority test events shall be allowed to go beyond the test period.
N2	Multiple Assets (T=O)	KSA	The model shall allow multiple test assets to be tested simultaneously.
N3	Time Period Asset Availability (O)	APA	The model shall have a time period test asset availability constraint.
N4	Venue Distance (T=O)	KSA	The model shall minimize test movement between test venues.
N5	Event Priority Placement (T=O)	KSA	The model shall place test events based on priority.
N6	Multiple Venues (T=O)	APA	The model shall allow multiple test venues to be used at the same time.
N7	Venue Choice by Event (T=O)	APA	The model shall allow test venue choice by test event.
N8	Multiple Events (T=O)	APA	The model shall allow multiple test events to occur at the same time,
N9	Precedence Relationship (T=O)	APA	The model shall have test event predecessor and successor relationship constraints.
N10	Deadline for each Priority (T=O)	APA	The model shall place test assets based on a deadline for each priority type.
N11	Schedule Test Events (T=O)	KPP	The model shall minimize the time period used for test events.
N12	MS Excel Input (T=O)	APA	The model shall allow TE personnel to input information in MS Excel.

Need #	Title	Tier	Operational Needs
N13	MS Excel Output (T=O)	KPP	The model shall output schedules in a MS Excel format showing each vehicle, using colors for test site, and using blocks that aggregate the information into the month.
N14	Model in MS Excel (O)	APA	The model shall use MS Excel only. This means that a specialized tool will not be used for the model.

These model operational needs are prioritized by tier and, as discussed in CJCSI 3170.01 (2015b, D-61), are identified as a KPP, key system attribute (KSA) or additional performance attribute (APA). Key performance parameters are the highest level capability and require involvement at the highest level to change them. If KPPs are not met, the program itself is in jeopardy, since these capabilities are the basis for the program’s existence. Key system attributes are the second most important tier, but the milestone decision authority (MDA) has the authority to change them. Additional performance attributes are the third level of priority and can be changed by the capability drafter. Objective capabilities are the fourth level of priority, as they are desired capabilities.

D. RELATED PROBLEMS AND MODELS

There are many models that are available to assess a schedule once it has been developed. Providing a schedule model based on inputs and constraints is a much more difficult activity.

Research is performed relative to other schedule optimization problems, models and methods used to solve the problems, and the applicability of the problems to the schedule optimization capabilities needed. As illustrated in Figure 5 under operational needs, the first step in the systems engineering “V” includes performing market surveys. As these models have already been developed, the question is whether they could be modified to address the

operational needs of PMO test scheduling using the operational needs expressed in Table 1.

The first optimization decision making model explored is “Using Optimization to Improve NASA Extravehicular Activity Planning,” hereafter referred to in this thesis as the extravehicular activity (EVA) model. This model prioritizes tasks for one to two crew and tasks with different durations. The EVA model addressed tasks with different priorities, tasks with predecessor relationships, tasks at different locations, and tasks with time period availability constraints over a given time period. Tasks also have information about whether they are mandatory, the number of crew required, whether they have a contamination risk, and if they have to be completed if started, referred to as “bingo time” (Felker 2012, 36).

The second optimization decision making model explored is “Pacific Fleet Submarine Tender Optimization,” hereafter referred to in this thesis as “SUB,” The SUB model prioritizes maintenance tasks for workers at different locations over a given time period while minimizing travel. Tasks also have information about “whether or not tender presence is required; the estimated total number of worker-days required; the beta_max number of workers that can simultaneously work on each task; the types of maintenance workers that can perform the task; and task due dates” (Pickett 2013, i).

The third optimization decision making model explored is “An optimization of The Basic School Military Occupational Skill Assignment Process,” hereafter referred to in this thesis as military operational skills (MOS) model. The MOS model assigns MOSs to Lieutenants based on class and leadership standing, available MOSs and preferences (Boersma 2003, 49).

The fourth optimization decision making model explored is “Optimizing Marine Security Guard Assignments,” hereafter referred to in this thesis as the marine security guards (MSG) model.” The MSG model “assign[s] [MSGs] to billets and to balance MSG experience levels across all detachments” (Enoka

2011, 15). MSG assignments are based on detachment attributes and billet attributes of experience level, rank, restrictions, region, gender, tier, preference, priority, and qualification (Enoka 2011, 21).

The fifth optimization decision making model explored is “Optimizing Ship-to-Shore Movement for Hospital Ship Humanitarian Assistance Operations,” hereafter referred to in this thesis as the Hospital model. The hospital model “determine(s) transportation asset… routing and loading to effect the movement of personnel and patients between ship and ashore mission site” (Ward 2008, 5). This problem addresses daily routing of multiple assets and multiple asset types through different nodes, with priority sites. This model is constrained by how many assets can be at each node simultaneously and when and where personnel need to be picked up and delivered (Ward 2008, 29).

The operational needs identified in Table 1 are assessed for each model. Table 2 shows the operational needs and what each of the models assessed addresses against these needs. A “Yes” indicates that the model addresses the operational need. A “No” indicates that the model does not address the identified operational need.

In addition to the operational need assessment for each model, the problem type and objective function are identified in Table 2 for information and comparison.

Table 2. Model Alternatives Explored

Model Capability	EVA Model	SUB Model	MOS Model	MSG Model	Hospital Model
Low Priority Test Events (N1)	No	No	No	No	No
Multiple Assets (N2) KSA	Yes, Two people	Yes. Multiple people	Yes. Multiple People	Yes. Multiple People	Yes
Time Period Asset Availability (N3)	Yes	Yes	No	No	No
Venue Distance (N4) KSA	Yes. Location Proximity	Yes. Different locations	No	No	Yes
Event Priority Placement (N5) KSA	Yes, Priority tasks	Yes. Priority tasks	Yes. Class standing takes MOS priority	Yes. Billet priority placement	Yes
Multiple Venues (N6)	Yes, Multiple Locations on the space station	Yes	Yes. Multiple MOS Types	Yes	Yes
Venue Choice by Event (N7)	Yes, Chose location for task	No	Yes. MOS preferences	Yes. MSG preferences	No
Multiple Events (N8)	Yes, Multiple tasks	Yes. Multiple tasks	No	No	Yes
Precedence Relationships (N9)	Yes	Yes	No	No	No
Deadline for each Priority (N10)	No	Yes. Task completion dates	No	No	No
Schedule Test Events (N11) KPP	Yes. Schedule EVA Tasks	No. Schedule SUB Maintenance Tasks	No. Assign Personnel to MOS	No. Assign MSGs to Embassy Posts	No. Schedule Transportation Assets
MS Excel Input (N12)	Yes	Yes	Yes	Yes	Unknown
MS Excel Output (N13) KPP	No. GAMS	No. GAMS	Yes	Yes	Unknown
Model in MS Excel (N14)	No. Uses GAMS	No. Uses GAMS	No. Uses solver.com	Yes	No. Xpress-MP
Problem Type	Mixed Integer Linear	Mixed Integer Linear	Integer Linear	Integer Linear Multi-commodity Network Flow	Multi-objective Mixed Integer Linear
Objective Function	Maximize Priority Tasks	Minimize completion time and late tasks	Minimize MOS not meeting Lt choice list based on class standing	Minimize MSG not assigned to Billets without needed experience	Minimize Transportation Schedule

While there is much similarity between our test schedule problem and the EVA problem, there is a significant difference. Our problem is to complete all of the tasks within a certain timeframe, with different completion times based on priority and with some tasks allowed to go beyond the timeframe. The EVA problem is to decide which tasks to perform based on priority within a given timeframe. Since this problem has different constraints and due to the additional complexity of our problem, the EVA problem solution is not used as a starting point for our model.

There is considerable similarity between our test schedule problem and the SUB problem. The differences are that we have multiple venues to choose from, and our specific problem and constraints are different. Our problem is to minimize the completion time of all tasks. Although similar in approach, the SUB problem solution is not used as a starting point for our model due to these differences.

The MOS problem is very simplistic in comparison with our schedule problem, and does not have much similarity with our problem. Therefore, this problem solution is not used as a starting point for our model.

Like the MOS problem, the MSG problem is very simplistic in comparison with our schedule problem, and does not have much similarity with our problem. Thus, the MSG problem solution is not used as a starting point for our model.

There is some similarity between our test schedule problem and the Hospital problem. We have multiple venues to choose from, we have precedence, and we have priority completion times, whereas the Hospital problem does not. Also, our specific problem and constraints are different. Due to these many differences, the Hospital problem solution is not used as a starting point for our model.

As part of model review, there are two other optimization decision making models that are also explored. These two models incorporate cost into the model.

The first cost optimization decision making model explored is “The United States Army’s Multi-period Optimal Readiness Allocation Model,” hereafter referred to in this thesis as “EQT.” This model “maximize(s) unit readiness by determining equipment (re)distribution plan for every year of the POM,” “measures readiness as a weighted sum of unit S-ratings and LIN S-ratings across all units,” and “expands it over the years of the planning horizon” (Parsons 2011, 18). In the EQT model, “Unit S-ratings weights are assigned based on the priority of the unit. A similar construct is used to assign each unit’s LIN S-rating weights” (Parsons 2011, 18).

The second cost optimization decision making model explored is “Cost-Constrained Project Scheduling with Task Durations and Costs that may Increase over Time Demonstrated with the U.S. Army Future Combat System,” hereafter referred to in this thesis as “Sch Cost.” The Sch Cost model explores “feasible task schedules, selecting those that minimize the length of the project critical path while observing annual and project constraints” (Grose 2015, 19).

While there is cost associated with test schedules, in PMAAA, costs are determined by the TE planners after the schedules are built. Therefore, these models are not considered as potential solutions to the problem at hand. It is noted, however, that if the model developed by this thesis is matured, that the cost of each schedule could potentially be incorporated into the output of the model and could be included in the decision process of the model itself.

Based on this model AoA review against the operational needs, a model is determined to be needed to address the problem statement. Additionally, based on the complexity of the problem, it is expected the Microsoft Excel, even with solver implemented, may not be able to address this complex problem.

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III. MODEL REQUIREMENTS AND MODEL DEVELOPMENT

A. IDEF0 MODEL REPRESENTATION

As illustrated in Figure 5, the next step in the systems engineering "V" is the decomposition of the operations needs into system requirements. The requirements and verification criteria are developed from the operational needs and the problem statement.

Developing system requirements results in a large number of requirements. Thus, having a method to organize the requirements is helpful. IDEF0 is used in this research to perform this requirement organizational function. The majority of system requirements are functional requirements, which means that the system requirements define the functions that the system needs to perform. Functional analysis and synthesis is the process used in system engineering to generate the system functional requirements.

IDEF0 is a method commonly used in systems engineering when performing functional analysis and synthesis, and is defined by DAU as

> a model that consists of a hierarchical referenced to each other. The two primary modeling components are: functions (represented on a diagram by boxes), and data and objects that interrelate those functions (represented by arrows). The position at which the arrow attaches to a box conveys the specific role of the interface. The controls enter the top of the box. The inputs, the data or objects acted upon by the operation, enter the box from the left. The outputs of the operation leave the right-hand side of the box. Mechanism arrows that provide supporting means for performing the function join (point up to) the bottom of the box. (DAU 2001, 51)

Using the IDEF0 method to structure the functional requirements of the model, Figure 9 is developed for the model requirements. Figure 9 shows the inputs, the outputs, the controls and constraints, and the mechanisms, resources, and tools of the model. Figure 9 provides short statements that are the titles of the detailed requirements in the model requirements Section.

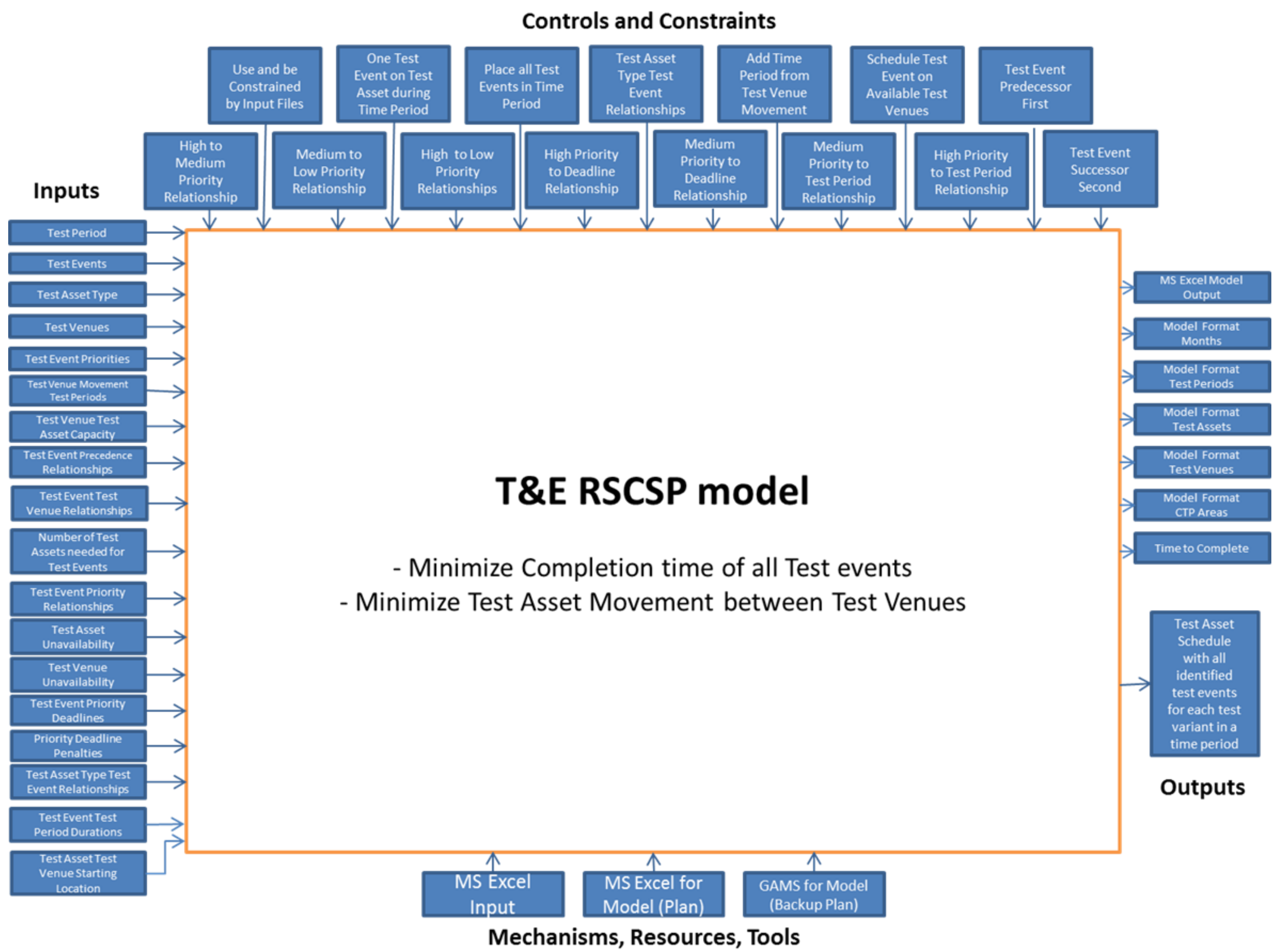

Figure 9. IDEF0 Model Representation

B. MODEL DEFINITIONS

Part of developing model requirements is having common definitions in order to avoid misunderstanding. Definitions provided here are adapted from the problem statement, which was developed in coordination with Shane A. Edwards (Edwards 2015, 15), and are given in alphabetical order:

Test Asset. The item that is being tested. Test assets may have test periods during which they are unavailable. There may be multiple test assets of each test asset type.

Test Asset Type. A variant, or type, of test asset, that is sufficiently different from another test asset such that it requires separate testing for all or some of the test events planned for the other test asset type(s). There may be one or more test asset types that go through test events.

Test Event. An event where specific tests are performed on a test asset. A test event may apply to one or more test asset type(s), may require one or more test assets, and may require one or more test asset types.

Test Event Precedence. A test event relationship that requires that a specific test event be completed before another test event can begin. Test event precedence may be test asset type specific.

Test Event Priority. The priority state of the test event. Values of the test event priority are high, medium, and low.

Test Event Priority Deadline. The test event priority deadline is defined as the last time period that a test event can be completed. High and medium priority test events have test event priority deadlines. Low priority test events do not have a deadline and can be completed after the test period.

Test Period. The time period available to perform a test event. It consists of one or more test periods. When moving test assets between test venues, test periods are needed for movement to, and for inspection at, the receiving test venue.

Test Venue. A facility where a test asset can be tested. There may be multiple test venues that can complete a specific test event. Not all test venues can complete a given test event. There may be time periods where a test venue is not available. Test venues are limited in the number of test assets that they can accommodate. Test venues may perform simultaneous test events on test assets at the test venue.

Time Period. A duration of time, such as days. Test events can be allocated to test venues during the time period.

C. MODEL REQUIREMENTS

The test and evaluation resource constrained scheduling problem (RSCSP) model requirements and verification criteria are provided in this section. These requirements are broken down in detail in Tables 3 through 6. The requirements found in these tables correspond with Figure 9. Table 3 corresponds with IDEF0 model input requirements (requirement "Para #" of 1.x). Table 4 corresponds with IDEF0 model control and constraint requirements (requirement "Para #" of 2.x). Table 5 corresponds with IDEF0 model mechanisms, resources and tools requirements (requirement "Para #" of 3.x). Table 6 corresponds with IDEF0 model output requirements (requirement "Para #" of 4.x). The blocks given in the Figure 9 IDEF0 model correspond with the titles of the requirements that are provided in Tables 3 through 6. Requirement and verification details are given in the "Requirement and Verification Criteria" column in Tables 3 through 6. The "Need # Relationship" column in Tables 3 through 6 provides a relationship between the model requirement and operational need capabilities of Table 1.

For simplicity, requirements and verification criteria have been combined into a single requirement and verification criteria. Interpretation of these tables means that a requirement consists of the first table row combined with each row below the first row. For example, the 1.1 requirement is pulled from Table 3 rows 1.0 (The TE RSCSP model shall accept the following input, which is verified by reviewing the model input file) and 1.1 (Test Period (T=O)). Therefore, the 1.1

requirement is “The TE RSCSP model shall accept the following input, which is verified by reviewing the model input file: Test Period (T=O).” The requirements are verified in Chapter IV and validated in Chapter V using the input files, the model generated output file, and the manually converted 3-D TE schedules.

Table 3 provides the TE RSCSP model 1.x requirements, the model verification criteria, and the requirement relationship to the operational need for model input requirements, using the “Inputs” boxes from Figure 9.

Table 3. Model Input Requirements

Para #	Requirement and Verification Criteria	Need # Relationship
1.0	The TE RSCSP model shall accept the following input, which is verified by reviewing the model input file:	N/A
1.1	Test Period (T=O)	N11
1.2	Test Events (T=O)	N5
1.3	Test Asset Type (T=O)	N2
1.4	Test Venues (T=O)	N7
1.5	Test Event Priorities (T=O)	N5
1.6	Test Venue Movement Test Periods (T=O)	N4
1.7	Test Venue Test Asset Capacity (T=O)	N6
1.8	Test Event Priority Relationships (T=O)	N5
1.9	Test Event Test Venue Relationships (T=O)	N7
1.10	Test Event Precedence Relationships (T=O)	N9
1.11	Test Event Test Period Durations (T=O)	N11
1.12	Number of Test Assets Needed for Test Events (T=O)	N2
1.13	Test Asset Type Test Event Relationships (T=O)	N2
1.14	Test Asset Test Venue Starting Location (T=O)	N7
1.15	Test Asset Unavailability (O)	N3
1.16	Test Venue Unavailability (O)	N6
1.17	Test Event Priority Deadlines (T=O)	N10
1.18	Priority Deadline Penalties (T=O)	N10

Table 4 provides the TE RSCSP model 2.x requirements, the model verification criteria, and the requirement relationship to the operational need for model control and constraint requirements, using the “Control and Constraint” boxes from Figure 9.

Table 4. Model Control and Constraint Requirements

Para #	Requirement and Verification	Need # Relationship
2.0	Controls and Constraints (T=O). The TE RSCSP model shall accept and use model controls and constraints, which are verified by reviewing the model files and 3-D conversions:	N/A
2.1	Test Period (T=O)	N11
2.1.1	One Test Event on Test Asset during Time Period (T=O)	N5
2.1.2	Place all Test Events in Time Period (T=O)	N5
2.1.3	Test Event Test Period Durations (T=O)	N11
2.2	Test Events (T=O)	N5
2.3	Test Asset Type (O)	N2
2.4	Test Venues (T=O)	N7
2.5	Test Event Priority	N/A
2.5.1	Test Event Priority Relationships (T=O)	N5
2.5.2	High to Medium Priority Relationship (T=O)	N5
2.5.3	Medium to Low Priority Relationship (T=O)	N5
2.5.4	High to Low Priority Relationships (T=O)	N5
2.6	Test Venue Movement Test Periods (T=O)	N4
2.6.1	Add Time Period from Test Venue Movement (T=O)	N4
2.6.2	Schedule Test Event on Available Test Venues (T=O)	N7
2.7	Test Venue Test Asset Capacity (T=O)	N7
2.8	Test Asset Test Venue Starting Location (T=O)	N7
2.9	Test Event Test Venue Relationships (T=O)	N7
2.10	Test Event Precedence Relationships (T=O)	N9
2.10.1	Test Event Predecessor First (T=O)	N9
2.10.2	Test Event Successor Second (T=O)	N9
2.11	Number of Test Assets Needed for Test Events (T=O)	N8
2.12	Low Priority Schedule Relationship (O)	N1
2.13	Test Asset Unavailability (O)	N3
2.14	Test Venue Unavailability (O)	N7
2.15	Test Event Priority Deadlines (T=O)	N10
2.15.1	High Priority to Deadline Relationship (T=O)	N10
2.15.2	Medium Priority to Deadline Relationship (T=O)	N5
2.15.3	High Priority to Test Period Relationship (T=O)	N5
2.15.4	Medium Priority to Test Period Relationship (T=O)	N5

Table 5 provides the TE RSCSP model 3.x requirements, the model verification criteria, and the requirement relationship to the operational need for

model mechanisms, resources and tools requirements, using the "Mechanisms, Resources and Tools" boxes from Figure 9.

Table 5. Model Mechanisms, Resources and Tools Requirements

Para #	Para Title	Requirement and Verification Criteria	Need # Relationship
3.0	Mechanisms, Resources and Tools	The TE RSCSP model tool requirements shall be verified by reviewing the model files:	N/A
3.1	MS Excel Input (T=O)	The format of the TE RSCSP model input files shall be MS Excel.	N12
3.2	MS Excel Model (Objective)	The TE RSCSP model shall use MS Excel for calculation, output and display similar to current TE output.	N14

Table 6 provides the TE RSCSP model 4.x requirements, the model verification criteria, and the requirement relationship to the operational need for model output requirements, using the "Outputs" boxes from Figure 9.

Table 6. Model Output Requirements

Para #	Para Title	Requirement and Verification Criteria	Need # Relationship
4.0	Model Outputs	The TE RSCSP model output requirements shall be verified by reviewing the model output files:	N13
4.1	MS Excel Model Output (T=O)	The TE RSCSP shall use MS Excel for the model output.	N13
4.2	Model Format (T=O)	The TE RSCSP Model shall be in the same format as the TE manual method:	N13
4.2.1	Model Format - Months (T=O)	Months	N13
4.2.2	Model Format - Test Periods (T=O)	Test periods	N13
4.2.3	Model Form - Test Assets (T=O)	Test assets	N13

Para #	Para Title	Requirement and Verification Criteria	Need # Relationship
4.2.4	Model Format - Test Venues (T=O)	Test venues	N13
4.2.5	Model Format - CTP Areas (T=O)	CTP areas	N13
4.3	Time to Complete (T=O)	The TE RSCSP model shall provide output in less than or equal to 10 minutes.	N13

D. TEST SCHEDULING MODEL DEVELOPMENT

As illustrated in Figure 5, the next step in the systems engineering "V" is model development. The initial plan for the model development is to use MS Excel as the tool of choice. The TE personnel that will be using this tool currently use MS Excel for test schedule development. Although multiple iterations of an MS Excel model were attempted, MS Excel was found not to be powerful enough to address the problem. Therefore, tools meant specifically for advanced optimization, general algebraic modeling system (GAMS) with a CPLEX solver, were used to address the problem. The TE RSCSP optimization model was generated by Shane Edwards (Edwards 2015).

IV. MODEL VERIFICATION

As illustrated in Figure 5, the next step in the systems engineering "V" is model verification. Model verification is performed through review of model input files and through review of the manually generated schedules developed from a model output file. The input files and the output file used for this assessment are from a model run provided by Shane A. Edwards (Edwards 2015). The model run used for verification is associated with a file provided by the TE planners.

The assessments that follow present verification assessments against this model run and use the terminology of MET, NOT MET, PARTIALLY MET, and NOT VERIFIED. "MET" means that the requirement has been assessed to have been met based on the verification criteria and the data provided. "NOT MET" means that the requirement has been assessed *not* to have been met based on the verification criteria and the data provided. "NOT VERIFIED" means that the requirementcannot be verified based on the verification criteria and the data provided due to lack of data or inaccurate data. "PARTIALLY MET" means that the requirement has been assessed to have been partially met based on the verification criteria and the data provided; an assessment of PARTIALLY MET indicates that a portion of the requirement is either NOT MET, or NOT VERIFIED.

A. MODEL INPUTS VERIFICATION

The model is verified against the 1.x model input requirements, contained in Table 3. Since there is a single set of input files, the 1.x model input requirements apply to all of the schedules developed by this model run.

In order to assess the model inputs from Appendix A against the 1.x model input requirements from Table 3, an understanding is needed of the relationship between the model variables, the input file names, and the model requirements. Table 7 provides this relationship. Table 7 columns are explained as:

- "Input #" provides numbering for the Table 7 row.
- "Para # and Title" provides the relationship to Table 3.
- "Formulation Variable" provides the related problem formulation variables.
- "File Name" identifies the related input filename. Model input filenames consist of MS Excel .csv files and are contained in Appendix A.

Table 7. Model Inputs Relationship to Model and Model Files

Input #	Para # and Title	Formulation Variable	File Name
I1	1.1 Test Period	p	p.csv
I2	1.2 Test Events	t	t.csv
I3	1.3 Test Asset Type	a	a.csv
I4	1.4 Test Venues	v	v.csv
I5	1,7 Test Event Priorities	i	i.csv
I6	1.6 Test Venue Movement Test Periods	$m\_periods_{v,v'}$	m_periods.csv
I7	1.7 Test Venue Test Asset Capacity	v_cap_v	v_cap.csv
I8	1.8 Test Event Priority Relationships	i_t	ti.csv
I9	1.9 Test Event Test Venue Relationships	V_t	vt.csv
I10	1.10 Test Event Precedence Relationships	R_t	rt.csv
I11	1.11 Test Event Test Period Durations	$t\_periods_t$	t_data.csv
I12	1.12 Number of Test Assets Needed for Test Events	a_rec_t	t_data.csv
I13	1.13 Test Asset Type Test Event Relationships	$a\_type\_req_{ta}$	ta_data.csv
I14	1.14 Test Asset Test Venue Starting Location	$a\_rec_{a,vg,p}$	a_data.csv
I15	1.15 Test Asset Unavailability	$unavail_{a,v,p}$	a_data.csv
I16	1.16 Test Venue Unavailability	$unavail_{a,v,p}$	a_data.csv
I17	1.17 Test Event Priority Deadlines	$deadline_i$	i_data.csv
I18	1.18 Priority Deadline Penalties	$penalty_i$	i_data.csv

Based on the relationships identified in Table 7, the input files contained in Appendix A are assessed against the model 1.x input requirements contained in Table 3. Because there is a single set of input files, the 1.x model input requirements apply to all of the schedules developed by this model run. Verification assessment results, against the 1.x requirements, are given in the last column, "Verification & Rationale," of Table 8.

Table 8. Model Input Verification

Para #	Para Title and Verification Criteria	Verification & Rationale	
1.0	Model Inputs. The TE RSCSP model shall accept the following input, which is verified by reviewing the model input file:	N/A	
1.1	Test Period (T=O)	MET	p.csv has data
1.2	Test Events (T=O)	MET	t.csv has data
1.3	Test Asset Type (T=O)	MET	a.csv has data*
1.4	Test Venues (T=O)	MET	v.csv has data
1.5	Test Event Priorities (T=O)	MET	i.csv has data
1.6	Test Venue Movement Test Periods (T=O)	MET	m_periods.csv has data
1.7	Test Venue Test Asset Capacity (T=O)	MET	v_cap.csv has data
1.8	Test Event Priority Relationships (T=O)	MET	ti.csv has data
1.9	Test Event Test Venue Relationships (T=O)	MET	vt.csv has data
1.10	Test Event Precedence Relationships (T=O)	MET	rt.csv has data
1.11	Test Event Test Period Durations (T=O)	MET	t_data.csv has data
1.12	Number of Test Assets Needed for Test Events (T=O)	MET	t_data.csv has data
1.13	Test Asset Type Test Event Relationships (T=O)	MET	ta_data.csv has data
1.14	Test Asset Test Venue Starting Location (T=O)	MET	a_data.csv has data
1.15	Test Asset Unavailability (O)	MET	a_data.csv has data
1.16	Test Venue Unavailability (O)	MET	a_data.csv has data
1.17	Test Event Priority Deadlines (T=O)	MET	i_data.csv has data
1.18	Priority Deadline Penalties (T=O)	MET	a_data.csv has data

*Note: Only one asset type given in this example.

The model verification assessment for the 1.x model input requirements, contained in Table 3, indicate that all 18 model input requirements in Table 8 are assessed as MET.

B. MODEL MECHANISMS, RESOURCES, AND TOOLS VERIFICATION

Next, verification of the model against the 3.x model requirements (mechanisms, resources, and tools), contained in Table 5, is performed. Since there is a single set of input and output files, these requirements apply to all of the schedules developed by this model run. The model 3.x requirements (mechanisms, resources, and tools) are assessed against the input and output files contained in Appendix A. Verification assessment results, against the 3.x requirements, are given in the last column, "Verification & Rationale," of Table 9.

Table 9. Model Mechanisms, Resources and Tools Requirements Verification

Para #	Para Title	Requirement Verification Criteria	**Verification & Rationale**
3.0	Mechanisms, Resources and Tools	The TE RSCSP model tool requirements shall be verified by reviewing the model files:	Not Applicable
3.1	MS Excel Input (T=O)	The format of the TE RSCSP model input files shall be MS Excel.	MET
3.2	MS Excel Model (Objective)	The TE RSCSP model shall use MS Excel for calculation, output and display similar to current TE output.	NOT MET GAMS and CMPLX Solver is used for implementation. Model input files use MS Excel .csv files.

Results of the model verification assessment against the 3.x model requirements (mechanisms, resources, and tools) indicate that the one T=O requirement for MS Excel input files is assessed as MET. The one 3.x objective requirement for MS Excel model implementation is assessed as NOT MET.

C. MODEL OUTPUT VERIFICATION

Next, verification of the model against the 4.x model output requirements, contained in Table 6, is performed. There is a single output file that contains all of the schedules developed by this model run. The model 4.x output requirements are assessed against the single output file reference in Appendix A. Verification assessment results against the 4.x requirements are given in the last column, “Verification & Rationale,” of Table 10.

Table 10. Model Output Requirement Verification

Para #	Para Title	Requirement and Verification Criteria	Verification & Rationale
4.0	Model Outputs	The TE RSCSP model output requirements shall be verified by reviewing the model output files:	Not Applicable
4.1	MS Excel Model Output (T=O)	The TE RSCSP shall use MS Excel for the model output.	NOT MET
4.2	Model Format (T=O)	The TE RSCSP Model shall be in the same format as the TE manual method:	The current output file must be converted from machine format to a MS Excel human readable format.
4.2.1	Model Format - Months (T=O)	Months	NOT MET, See 4.2
4.2.2	Model Format - Test Periods (T=O)	Test periods	NOT MET, See 4.2
4.2.3	Model Form - Test Assets (T=O)	Test assets	NOT MET, See 4.2
4.2.4	Model Format - Test Venues (T=O)	Test venues	NOT MET, See 4.2
4.2.5	Model Format - CTP Areas (T=O)	CTP areas	NOT MET, See 4.2
4.3	Time to Complete (T=O)	The TE RSCSP model shall provide output in less than or equal to 10 minutes.	NOT VERIFIED

Results of the model verification assessment against the 4.x model output requirements, contained in Table 6, indicate that six of the seven T=O model output requirements in Table 10 are NOT MET. One of the seven T=O model output requirements (Time to Complete) is NOT VERIFIED.

D. MODEL CONTROL AND CONSTRAINT REQUIREMENT VERIFICATION

Lastly, verification of the model against the 2.x model requirements (control and constraint), contained in Table 4, is performed. These requirements apply to each of the five schedules developed by this model run.

Before the schedules can be assessed, they need to be developed from the model output file. The model output file is given in the format of test venue, test period, test event, number of test assets assigned to test, and total assets in test, as shown in Figure 10. This information is provided for each schedule.

```
schedule of tests completed
ATC_MD
  p001
   t25 Initial Inspection and Safety started:
p001 testing  4 test assets
   .                                          4 total
in test
             .
             .
  p034
   t04 Land Mode Braking      started: p034
testing  1 test assets
   t11 Rolling Resistance      started: p032
testing  1 test assets
   t12 Fuel Consumption_land  started: p031
testing  1 test assets
   t40 Physical Characteristics  started: p031
testing  1 test assets
                                              4 total
in test
```

Figure 10. Example of Model Output. Source: Edwards (2015).

The model output information, for each of the five schedules, is manually translated from the model output into MS Excel schedules, similar to how the TE planner schedules are generated. The schedule generated is called a 3-D schedule because it contains the items given in the 3-D diagram of Figure 8: test asset (y-axis), test period (x-axis), and test venue (color). Each of these detailed schedules is individually provided in Appendix B for each of the five schedules in the form of monthly schedules with daily test information. An example of model output translated into a 3-D schedule is provided in Figure 11.

Test Asset	P041	P042	P043	P044	P045	P046
TA1	**LM** **t12**	**LM** **t12**	**LM** **t12**	**F** **t64**	**F** **t64**	**F** **t64**
TA2	**LM** **t59**	**RGT1** **t59**	**RGT1** **t59**	**RGT1** **t59**	**RGT1** **t59**	**RGT1** **t59**
TA3	*S/HF* *t40*	*S/HF* *t40*	*S/HF* *t40*	*S/HF* *t40*	*S/HF* *t40*	*S/HF* *t40*
TA4	**S/HF** **t28**	**S/HF** **t28**	**S/HF** **t28**	**S/HF** **t28**	**S/HF** **t28**	**S/HF** **t28**
TA5	*S* *t53*	*S* *t53*	*S* *t53*	*S* *t53*	*S* *t53*	*S* *t53*
TA6	**RGT1** **t58**	**RGT1** **t58**	**RGT1** **t58**	**RGT1** **t58**	**RGT1** **t58**	**RGT1** **t58**
TA7	**WM** **t15**	**WM** **t15**	**WM** **t15**	**S/HF** **t37**	**S/HF** **t37**	**S/HF** **t37**

Figure 11. Example of Generated 3-D Detailed Monthly Schedule

In the manually generated 3-D detailed monthly schedules:

- Test assets are given on the y-axis as test asset 1 (TA1) through test asset 7 (TA7).

- Test periods are given on the x-axis as test period 1 (P001) through test period xyz (Pxyz).
- The cells where the x and y axis intersect are colored based on test venue: Amphibious Vehicle Test Branch (AVTB) = blue, Aberdeen Test Center (ATC) = green, Yuma Proving Ground (YPG) = purple, and White Sands Missile Range (WSMR) = salmon.
- The interior cells contain: the associated CTP area, the test event, and the test priority indicated by text font.
- The top line of the cells in the interior of the table displays the functional test CTP area: LM = land mobility, F = firepower, RGT1 = reliability growth testing 1, S/HF = safety/human factors, WM = water mobility, and S = survivability.
- The entire CTP area list is given in Table 14. The CTP area was not used by the model, but is provided in this manually generated set of schedules.
- The second line of the cells in the interior of the table contains the actual test event that is performed on that test asset during that time period. Examples of test events are t12 = fuel consumption, t64 = firing, t59 = RGT, t40 = physical characteristics, t28 = land mode ride quality, t53 = electromagnetic environmental effects (E3) testing_limited, t58 = RGT, t15 = plow in testing, and t37 = automotive toxic fumes in water. The entire list of test events for this model run is located in Appendix A, Table 31.
- The cells in the interior of the table are given a font based on priority: high = bold, medium = italic, and low = normal.

As an example, test asset TA1 in test period P041 is performing a high-priority, fuel-consumption test event, with a CTP area of land-mobility at test venue ATC. TA1 continues this testing in P042 and P043. TA1 transitions into a

high-priority, firing test event, with a CTP area of firepower in P044. TA1 continues this testing into P045 and P046. As another example, test asset TA3 performs a medium-priority, physical characteristics test event, with a CTP area of safety and human factors at test venue ATC for test periods T041 through T046.

The model output manually generated 3-D detailed monthly schedules, contained in Appendix B, are assessed against the model requirements (control and constraint). Based on these five schedule assessments, results are given in the last column, "Verification & Rationale," of Table 11.

Table 11. Model Control and Constraint Requirements Verification

Para #	Requirement and Verification Criteria	Verification & Rationale
2.0	Controls and Constraints (T=O). The TE RSCSP model shall accept and use model controls and constraints, which are verified by reviewing the model files and 3-D conversions:	The verification assessment is the same for all five schedules:
2.1	Test Period (T=O). Schedule is within the test period given in the test period input file.	MET
2.1.1	One Test Event on Test Asset during Time Period (T=O). Schedule does not show more than one test event in a time period on a test asset.	PARTIALLY MET
2.1.2	Place all Test Events in Time Period (T=O). Schedule places all identified test events in a test period.	MET
2.1.3	Test Event Test Period Durations (T=O). Schedule test event test period durations matches the test events test period input file.	MET
2.2	Test Events (T=O). Schedule includes all test events included in the test events input file.	MET
2.3	Test Asset Type (O). Schedule results places test events on the applicable test asset type based on the input file.	NOT VERIFIED

Para #	Requirement and Verification Criteria	Verification & Rationale
2.4	Test Venues (T=O). Schedule includes only the test venues included in the test venues input file.	MET
2.5	Test Event Priority	NOT APPLICABLE
2.5.1	Test Event Priority Relationships (T=O). Schedule results are constrained by the test event priority relationships input file	PARTIALLY MET
2.5.2	High to Medium Priority Relationship (T=O). Schedule starts high priority test events before medium priority test events.	PARTIALLY MET
2.5.3	Medium to Low Priority Relationship (T=O). Schedule starts medium priority test events before low priority test events.	NOT VERIFIED
2.5.4	High to Low Priority Relationships (T=O). Schedule starts high priority test events before low priority test events.	NOT VERIFIED
2.6	Test Venue Movement Test Periods (T=O). Schedule uses the test venue movement test periods based on the input file.	MET
2.6.1	Add Time Period from Test Venue Movement (T=O). Schedule shows that the time periods added to the schedule when the test asset moves to a new test venue are based on the input file.	MET
2.6.2	Schedule Test Event on Available Test Venues (T=O). Schedule shows that the test events are scheduled only on available test venues based on the input file.	MET
2.7	Test Venue Test Asset Capacity (T=O). The number of test assets located at each test venue on the schedule does not exceed the capacity identified in the input file.	NOT VERIFIED
2.8	Test Asset Test Venue Starting Location (T=O). Schedule test assets start at the venues identified in the test asset test venue input file.	MET

Para #	Requirement and Verification Criteria	Verification & Rationale
2.9	Test Event Test Venue Relationships (T=O). Schedule test events are performed at the test venues identified in the test event test venue relationships input file.	MET
2.10	Test Event Precedence Relationships (T=O). Schedule is constrained by the test event precedence relationships input file.	MET
2.10.1	Test Event Predecessor First (T=O). Predecessor test events are on the schedule before successor test events regardless of test event priority.	MET
2.10.2	Test Event Successor Second (T=O). Successor test events are on the schedule before predecessor test events regardless of test event priority.	MET
2.11	Number of Test Assets Needed for Test Events (T=O). Schedule uses the number of test assets needed for test events input file.	MET
2.12	Low Priority Schedule Relationship (O). Schedule results match the input file.	NOT VERIFIED
2.13	Test Asset Unavailability (O). Schedule places test assets only on available test assets based on the input file.	NOT VERIFIED
2.14	Test Venue Unavailability (O). Schedule results are constrained by the input file.	NOT VERIFIED
2.15	Test Event Priority Deadlines (T=O). Schedule results are constrained by the input file.	PARTIALLY MET
2.15.1	High Priority to Deadline Relationship (T=O) Schedule results start high priority test events before the high priority deadline.	MET
2.15.2	Medium Priority to Deadline Relationship (T=O). Schedule results start medium priority test events before the medium priority deadline.	NOT VERIFIED
2.15.3	High Priority to Test Period Relationship (T=O). Schedule results complete high priority test events before the test period completes.	MET

Para #	Requirement and Verification Criteria	Verification & Rationale
2.15.4	Medium Priority to Test Period Relationship (T=O). Schedule results complete medium priority test events before the test period completes.	MET

Results of the model verification assessment against the 2.x model output requirements (control and constraint), contained in Table 4, indicate that 17 of the 25 T=O model output requirements in Table 11 are MET, four are PARTIALLY MET, and four are NOT VERIFIED. Four of the four Objective 2.x model requirements (control and constraint) are NOT VERIFIED.

E. MODEL VERIFICATION SYNOPSIS

The detailed verification performed against the model is synopsized, showing verification against all of the model schedules, and is provided in Table 12. The model 2.x requirements (control and constraint) against each of the model schedules (beta_max, t_periods, beta_min, beta_mode and beta_mean) have resulted in the same assessment against all of them; therefore, only one verification result is provided in the Table 12.

Table 12. Synopsized Model Verification Results

Para #	Para Title	Verification
1.0	Model Inputs	N/A
1.1	Test Period (T=O)	MET
1.2	Test Events (T=O)	MET
1.3	Test Asset Type (T=O)	MET
1.4	Test Venues (T=O)	MET
1.5	Test Event Priorities (T=O)	MET
1.6	Test Venue Movement Test Periods (T=O)	MET
1.7	Test Venue Test Asset Capacity (T=O)	MET
1.8	Test Event Priority Relationships (T=O)	MET
1.9	Test Event Test Venue Relationships (T=O)	MET
1.10	Test Event Precedence Relationships (T=O)	MET

Para #	Para Title	Verification
1.11	Test Event Test Period Durations(T=O)	MET
1.12	Number of Test Assets Needed for Test Events (T=O)	MET
1.13	Test Asset Type Test Event Relationships (T=O)	MET
1.14	Test Asset Test Venue Starting Location (T=O)	MET
1.15	Test Asset Unavailability (O)	MET
1.16	Test Venue Unavailability (O)	MET
1.17	Test Event Priority Deadlines (T=O)	MET
1.18	Priority Deadline Penalties (T=O)	MET
2.0	Controls and Constraints	N/A
2.1	Test Period (T=O)	MET
2.1.1	One Test Event on Test Asset during Time Period (T=O)	PARTIALLY MET
2.1.2	Place all Test Events in Test Period (T=O)	MET
2.1.3	Test Event Test Period Durations (T=O)	MET
2.2	Test Events (T=O)	MET
2.3	Test Asset Type (O)	NOT VERIFIED
2.4	Test Venues (T=O)	MET
2.5	Test Event Priorities	N/A
2.5.1	Test Event Priority Relationships (T=O)	PARTIALLY MET
2.5.2	High to Medium Priority Relationship (T=O)	PARTIALLY MET
2.5.3	Medium to Low Priority Relationship (T=O)	NOT VERIFIED
2.5.4	High to Low Priority Relationships (T=O)	NOT VERIFIED
2.6	Test Venue Movement Test Periods (T=O)	MET
2.6.1	Add Time Period from Test Venue Movement (T=O)	MET
2.6.2	Schedule Test Event on Available Test Venues (T=O)	MET
2.7	Test Venue Test Asset Capacity (T=O)	NOT VERIFIED
2.8	Test Asset Test Venue Starting Location (T=O)	MET
2.9	Test Event Test Venue Relationships (T=O)	MET
2.10	Test Event Precedence Relationships (T=O)	MET
2.10.1	Test Event Predecessor First (T=O)	MET
2.10.2	Test Event Successor Second (T=O)	MET
2.11	Number of Test Assets Needed for Test Events (T=O)	MET
2.12	Low Priority Schedule Relationship (O)	NOT VERIFIED
2.13	Test Asset Unavailability (O)	NOT VERIFIED
2.14	Test Venue Unavailability (O)	NOT VERIFIED
2.15	Test Event Priority Deadlines (T=O)	PARTIALLY MET
2.15.1	High Priority to Deadline Relationship (T=O)	MET
2.15.2	Medium Priority to Deadline Relationship (T=O)	NOT VERIFIED
2.15.3	High Priority to Test Period Relationship (T=O)	MET

Para #	Para Title	Verification
2.15.4	Medium Priority to Test Period Relationship (T=O)	MET
3.0	Mechanisms, Resources and Tools	N/A
3.1	MS Excel Input (T=O)	MET
3.2	MS Excel Model (T=O)	NOT MET
4.0	Model Outputs	N/A
4.1	MS Excel Model Output (T=O)	NOT MET
4.2	Model Format (T=O)	NOT MET
4.2.1	Model Format - Months (T=O)	NOT MET
4.2.2	Model Format - Test Periods (T=O)	NOT MET
4.2.3	Model Form - Test Assets (T=O)	NOT MET
4.2.4	Model Format - Test Venues (T=O)	NOT MET
4.2.5	Model Format - CTP Areas (T=O)	NOT MET
4.3	Time to Complete (T=O)	NOT VERIFIED

V. MODEL VALIDATION

As illustrated in Figure 5, the next step in the systems engineering “V” is validation. For model validation, the model is assessed from multiple perspectives. The model is assessed in a combined DT/OT event using the model developer’s verification model inputs and outputs to assess the model from a validation perspective against the fourteen operational needs identified in Table 1. This assessment is followed by an operational assessment (OA) of the model schedules against PM AAA TE developed schedules for operational effectiveness (OE) and operational suitability (OS). This validation information is then aggregated against the COIs for assessment at a higher level.

A. VALIDATION AGAINST OPERATIONAL NEEDS

To perform validation assessment against the required capabilities, also known as operational needs, we look at the verification results relative to the operational needs, taking a step back from the deep dive of detailed requirements. The assessment of the operational needs relative to model verification results is provided in Table 13.

Table 13. Operational Needs and Model Verification Results

Need #	Title	Tier	Operational Needs	Model Verification Assessment
N1	Multiple Asset Types (O)	APA	The TE RSCSP model low priority test events shall be allowed to go beyond the test period.	NOT VERIFIED. Model data did not include data that would verify this. - NOT VERIFIED - 2.12 - Test Asset Type Test Event Relationships (O)
N2	Multiple Assets (T=O)	KSA	The TE RSCSP model shall allow multiple test assets to be tested simultaneously.	PARTIALLY MET. Although the model includes the constraint, model data did not include data that would verify that multiple test asset variants are included. For a single test asset type, this requirement is MET. - MET 1.3 - Test Asset Type (O) - MET 1.12 - Number of Test Assets Needed for Test Events (T=O) - MET 1.13 - Test Asset Type Test Event Relationships (T=O) - NOT VERIFIED - 2.3 - Test Asset Type (O)
N3	Time Period Asset Availability (O)	APA	The TE RSCSP model shall have a time period test asset availability constraint.	NOT VERIFIED. Although the model includes the constraint, model data did not include data that would verify this. - MET - 1.15 - Test Asset Unavailability (O) - NOT VERIFIED - 2.13 - Test Asset Unavailability (O)

Need #	Title	Tier	Operational Needs	Model Verification Assessment
N4	Venue Distance (T=O)	KSA	The TE RSCSP model shall minimize test movement between test venues.	MET. Test venue distance is addressed. - MET - 2.6 - Test Venue Movement Test Periods (T=O) - MET - 2.6.1 - Add Time Period from Test Venue Movement (T=O)
N5	Event Priority Placement (T=O)	KSA	The TE RSCSP model shall place test events based on priority.	PARTIALLY MET. Some test events of lower priority are tested before higher priorities. - MET - 1.2 - Test Events (T=O) - MET - 1.5 - Test Event Priorities (T=O) - MET - 1.8 - Test Event Priority Relationships (T=O) - PARTIALLY MET - 2.1.1 - One Test Event on Test Asset during Time Period (T=O) - MET - 2.1.2 - Place all Test Events in Test Period (T=O) - MET - 2.2 - Test Events (T=O) - PARTIALLY MET - 2.5.1 - Test Event Priority Relationships (T=O) - PARTIALLY MET - 2.5.2 - High to Medium Priority Relationship (T=O) - NOT VERIFIED - 2.5.3 - Medium to Low Priority Relationship (T=O) - NOT VERIFIED - 2.5.4 - High to Low Priority Relationships (T=O) - NOT VERIFIED - 2.15.2 - Medium Priority to Deadline Relationship (T=O) - MET - 2.15.3 - High Priority to Test Period Relationship (T=O) - MET - 2.15.4 - Medium Priority to Test Period Relationship (T=O)

Need #	Title	Tier	Operational Needs	Model Verification Assessment
N6	Multiple Venues (T=O)	APA	The TE RSCSP model shall allow multiple test venues to be used at the same time.	MET. - MET - 1.7 - Test Venue Test Asset Capacity (T=O) - MET - 1.16 - Test Venue Unavailability (O)
N7	Venue Choice by Event (T=O)	APA	The TE RSCSP model shall allow test venue choice by test event.	MET. Some of the specification requirements that connect to this are derived. - MET - 1.4 - Test Venues (T=O) - MET - 1.9 - Test Event Test Venue Relationships (T=O) - MET - 1.14 - Test Asset Test Venue Starting Location (T=O) - MET - 2.4 - Test Venues (T=O) - MET - 2.6.2 - Schedule Test Event on Available Test Venues (T=O) - NOT VERIFIED - 2.7 - Test Venue Test Asset Capacity (T=O) - MET - 2.8 - Test Asset Test Venue Starting Location (T=O) - MET 2.9 - Test Event Test Venue Relationships (T=O) - NOT VERIFIED - 2.14 - Test Venue Unavailability (O)
N8	Multiple Events (T=O)	APA	The TE RSCSP model shall allow multiple test events to occur at the same time,	MET - MET - 2.11 - Number of Test Assets Needed for Test Events (T=O)

Need #	Title	Tier	Operational Needs	Model Verification Assessment
N9	Precedence Relationship (T=O)	APA	The TE RSCSP model shall have test event predecessor and successor relationship constraints.	MET. - MET - 1.10 - Test Event Precedence Relationships (T=O) - MET - 2.10 - Test Event Precedence Relationships (T=O) - MET - 2.10.1 - Test Event Predecessor First (T=O) - MET - 2.10,2 - Test Event Successor Second (T=O)
N10	Deadline for each Priority (T=O)	APA	The TE RSCSP model shall place test assets based on a deadline for each priority type.	PARTIALLY MET. This requirement is not completely verified. Only high priority deadlines are verified. - MET - 1.17 - Test Event Priority Deadlines (T=O) - MET - 1.18 - Priority Deadline Penalties (T=O) - PARTIALLY MET - 2.15 - Test Event Priority Deadlines (T=O) - MET - 2.15.1 - High Priority to Deadline Relationship (T=O)
N11	Schedule Test Events (T=O)	KPP	The TE RSCSP model shall minimize the time period used for test events.	MET. - MET - 1.1 - Test Period (T=O) - MET - 1.11 - Test Event Test Period Durations (T=O) - MET - 2.1 - Test Period (T=O) - NOT VERIFIED - 2.1.4 - Test Venue Unavailability (T=O)
N12	MS Excel Input (T=O)	APA	The TE RSCSP model shall allow TE personnel to input information in MS Excel.	PARTIALLY MET. While MS Excel input files are used, data is not pulled directly from MS Excel. Some work and know-how is required to create input files. - MET - 3.1 - MS Excel Input (T=O)

Need #	Title	Tier	Operational Needs	Model Verification Assessment
N13	MS Excel Output (T=O)	KPP	The TE RSCSP model shall output schedules in a MS Excel Format showing each vehicle, using colors for test site, and using blocks that aggregate the information into the month.	NOT MET. This output is generated manually. - NOT MET - 4.1 - MS Excel Model Output (T=O) - NOT MET - 4.2.1 - Model Format – Months (T=O) - NOT MET - 4.2.2 - Model Format – Test Periods (T=O) - NOT MET - 4.2.3 - Model Format – Test Assets (T=O) - NOT MET - 4.2.4 - Model Format – Test Venues (T=O) - NOT MET - 4.2.5 - Model Format – CTP Areas (T=O) - NOT VERIFIED - 4.3 - Time to Complete (T=O)
N14	Model in MS Excel (O)	APA	The TE RSCSP model shall use MS Excel only. Note: This means that a specialized tool will not be used for the model.	NOT MET. The GAMS programming tool is used. - NOT MET - 3.2 - MS Excel Model (O)

Results follow of the DT/OT validation assessment of the capabilities:

- One of two KPPs is assessed as MET.
- One of three KSAs is assessed as MET.
- Four of six Threshold = Objective APAs are assessed as MET.
- Zero of three Objective APAs are assessed as MET.

B. TE PLANNING PROCESS SCHEDULES

The DT validation assessment against the capabilities is augmented by a validation assessment of the model results against a similar TE schedule development effort. The assessment uses a test schedule for a particular PM AAA program. Per Step 1 of Figure 6, the TE planner identifies what test events are required along with the number of days needed for each test event by reviewing the system performance specification. This information is provided in the form of a spreadsheet in Table 14 and is given by the “Test Plan/Sheet” and “Test Days Required” columns.

Per steps 2 and 3 of Figure 6, the PMO identifies the number of test assets and the test period for a particular course of action. For the example used in this model run, the TE planners use seven vehicles and a maximum schedule length of 190 days. This schedule length equates to about nine months, depending on how many days are used in the calculation of a month of test events. This assessment uses 20 days per month.

Per Step 4 of Figure 6, the TE planner updates the “Test Days Required” for the test event to a prior TE schedule planning spreadsheet. The other four columns of the TE spreadsheet are generated based on calculations relative to the “Test Days Required” column as shown in Table 14.

The “Test Days Required” column equates to 100% test asset availability. The “Pessimistic” column is based on a 30% test asset availability rate (“Test Days Required”/0.3). The “Most Likely” column is based on a 50% test asset

availability rate (“Test Days Required”/0.5). The “Optimistic” column is based on a 70% test asset availability rate (“Test Days Required”/0.7). The “Planning Estimate” column is based on the Pessimistic, Most Likely, and Optimistic columns (Pessimistic + Optimistic + 4 x “Test Days Required”/6).

The test events are identified for the entire test schedule for three different options by adding three columns of Best, Medium and Worst and through the use of “X”s in the three columns, as shown in Table 14.

Per Step 5 of Figure 6, the TE planner identifies the CTP area for each test event, precedence, test venues, and priorities, which is the first set of columns in Table 14.

The detailed test schedule planning for the specific schedule used to develop this model run is provided in Table 14.

All of the tables and figures provided in this section are based on data provided by the PM AAA TE group (Louis R. Ferguson and Albert B. Hanneman, email message to author, April 1, 2015).

Table 14. TE Detailed Schedule Planning with CTP Area, Precedence, Priority and Test Venue

CTP Area	Test Plan/Sheet	Prerequisite test	Test Venue	Priority of Tests	Test Days Required	Pessi-mistic	Most Likely	Opti-mistic	Planning Est	Best	Medium	Worst
LM	Tilt Table	Y side slopes	ATC	H	1	3	2	1	2	x	x	x
LM	Side Slopes		ATC	H	2	7	4	3	4	x	x	x
LM	Standard Obstacles		ATC	H	4	13	8	6	9	x	x	x
LM	Land Mode Braking		ATC	H	2	7	4	3	4	x	x	x
LM	Controlled Maneuverability		ATC	H	2	7	4	3	4	x	x	x
LM	Acceleration, Max. & Min Speeds		ATC	H	2	7	4	3	4	x	x	x
LM	Land Mobility Towing		ATC	M	2	7	4	3	4	x	x	x
LM	Longitudinal Slopes		ATC	H	3	10	6	4	6	x	x	x
LM	Drawbar Pull and Cooling System Heat Balance		ATC	M	10	33	20	14	21	x	x	x
LM	Dead Engine Braking		ATC	H	2	7	4	3	4	x	x	x
LM	Rolling Resistance	Y Draw bar pull test	ATC	M	2	7	4	3	4		x	x
LM	Fuel Consumption - land		ATC	H	4	13	8	6	9		x	x

CTP Area	Test Plan/Sheet	Prerequisite test	Test Venue	Priority of Tests	Test Days Required	Pessi-mistic	Most Likely	Opti-mistic	Planning Est	Best	Medium	Worst
S/HF	Initial Inspection and Safety Checkout	Y all WM test	AVTB	H	9	30	18	13	19	x	x	x
WM	Fuel Consumption - amphibious		AVTB	H	5	17	10	7	11		x	x
WM	Plow in testing	Y speed/powering, controlled maneuver ability, max Gross vehicle	AVTB	H	2	7	4	3	4	x	x	x
WM	Controlled Maneuverability		AVTB	H	2	7	4	3	4	x	x	x
WM	Speed and Powering		AVTB	H	2	7	4	3	4	x	x	x
WM	Maximum Gross Vehicle Weight		AVTB	H	2	7	4	3	4		x	x
WM	Line Passing & Towing		AVTB	H	1	3	2	1	2	x	x	x
WM	Surf Transit		AVTB	H	1	3	2	1	2	x	x	x
WM	Maneuver and Control with Weapon Station		AVTB	M	4	13	8	6	9			x
WM	Ship Operations		AVTB	H	2	7	4	3	4	x	x	x
WM	Multi-vehicle operations		AVTB	M	3	10	6	4	6	x	x	x

CTP Area	Test Plan/Sheet	Prerequisite test	Test Venue	Priority of Tests	Test Days Required	Pessi-mistic	Most Likely	Opti-mistic	Planning Est	Best	Medium	Worst
WM	Navigation and Obstacle Avoidance		AVTB	M	3	10	6	4	6			
S/HF	Initial Inspection and Safety Checkout	Y all test	ATC	H	9	30	18	13	19	x	x	x
S/HF	Driver Visibility/Crew Station Vision on Land		ATC	H	1	3	2	1	2			x
S/HF	Land Mode Ingress/Egress		ATC	H	1	3	2	1	2	x	x	x
S/HF	Land Mode Ride Quality		ATC	H	5	17	10	7	11	x	x	x
S/HF	Land Mode Interior Noise and Whole Body Vibration		ATC	H	5	17	10	7	11	x	x	x
S/HF	Driver Visibility/Crew Station Vision in Water		AVTB	H	1	3	2	1	2			x
S/HF	Ride Quality in Water		AVTB	H	4	13	8	6	9			
S/HF	Interior Noise and Whole Body Vibration in Water		AVTB	H	11	37	22	16	23			x
S/HF	Emergency Egress (land and water)		AVTB	H	2	7	4	3	4	x	x	x
S/HF	Maximum Air Flow		ATC	H	1	3	2	1	2			x

CTP Area	Test Plan/Sheet	Prerequisite test	Test Venue	Priority of Tests	Test Days Required	Pessi-mistic	Most Likely	Opti-mistic	Planning Est	Best	Medium	Worst
S/HF	Firepower Toxic Fumes	Y Man Gun & water gunnery testing	ATC	H	10	33	20	14	21			x
S/HF	Land Mode Automotive Toxic Fumes		ATC	H	5	17	10	7	11		x	x
S/HF	Automotive Toxic Fumes in Water		AVTB	H	5	17	10	7	11		x	x
S/HF	APU Noise		ATC/ AVTB	M	2	7	4	3	4			
S/HF	Transportability		ATC	M	20	67	40	29	43		x	x
S/HF	Physical Characteristics	Y Transportability	ATC	M	5	17	10	7	11	x	x	x
S/HF	Climatic Chambers		ATC/ YPG	M	20	67	40	29	43		x	x
F	Fire Control Inhibit Zones	Y Man Gun & water gunnery testing	ATC	H	1	3	2	1	2			
F	Fire Control System Check out	Y Man Gun & water gunnery testing	ATC	H	15	50	30	21	32			

CTP Area	Test Plan/Sheet	Prerequisite test	Test Venue	Priority of Tests	Test Days Required	Pessi-mistic	Most Likely	Opti-mistic	Planning Est	Best	Medium	Worst
F	Tracking / Lead	Y Man Gun & water gunnery testing	ATC	H	5	17	10	7	11			
F	Stabilization System Performance	Y Man Gun & water gunnery testing	ATC	H	3	10	6	4	6			
F	Sight / Boresight Retention		ATC	M	3	10	6	4	6			
F	Main Gun testing (Gunner firing)		ATC	H	15	50	30	21	32			
F	Main Gun testing (VC firing)		ATC	H	8	27	16	11	17			
F	COAX testing (Gunner firing)		ATC	H	2	7	4	3	4			
F	COAX testing (VC Firing)		ATC	H	2	7	4	3	4			
F	Water Gunnery (depends on requirements)		ATC/ AVTB	L	10	33	20	14	21			
S	NBC testing		EPG	L	10	33	20	14	21			
S	E3 testing	Y ship operations	WSMR	M	60	200	120	86	128		x	x
S	E3 testing (limited)		PAX		15	50	30	21	32	x	x	x

CTP Area	Test Plan/Sheet	Prerequisite test	Test Venue	Priority of Tests	Test Days Required	Pessi-mistic	Most Likely	Opti-mistic	Planning Est	Best	Medium	Worst
S	ROS testing		TBD	L	2	7	4	3	4			x
S	Other (Signatures, etc.)		TBD	M	25	83	50	36	53			x
C	C4I testing		AVTB	M		0	0	0	0			x
C	RF Testing		FH	L		0	0	0	0			x
C	Interoperability testing		AVTB	M		0	0	0	0			x
F	Limited Main Gun testing (Fly-Off)		ATC		8	27	16	11	17			
F	COAX testing (VC Firing)		ATC	H	2	7	4	3	4			

The first cells in the interior of Table 14 displays the functional test CTP area: LM = land mobility, F = firepower, S/HF = safety/human factors, WM = water mobility, C = communications, and S = survivability.

C. TE PLANNING SCHEDULES

The TE detailed planning numbers are assessed as to whether they will be tested before or after Milestone C. They are aggregated into total numbers by CTP areas for each test schedule. The aggregated schedule includes pessimistic, optimistic, and planning estimate. This particular example is for before MS-C. The TE values at the start of the schedule development are provided in Table 15. The first column in the interior of Table 15 displays the functional test CTP area: LM = land mobility, F = firepower, WM = water mobility, S/HF = safety/human factors, Surv = survivability, and Comm = communications.

Table 15. TE Aggregated Estimate (Days) by CTP Area

Test	Pessimistic	Planning Est.	Optimistic
LM	120	77	51
F	34	22	15
WM	67	43	29
S/HF	257	164	110
Surv	50	32	21
Comm	50	32	21

There are three schedules that are produced by the TE planners, which are called worse case, best case and planning estimate. From these, the final schedule is formed. These relate to the pessimistic, optimistic, and planning estimate columns, which are added up to form days and are then translated into months.

D. WORST CASE (PESSIMISTIC) SCHEDULE

Table 16 contains the beginnings of the worst case schedule. The last column titled “Actual” is an adjustment made by the TE planners after the initial monthly calculations are made.

Table 16. TE Worst Case Calculations

	Days	Months	Actual
LM	120	5.5	5.5
F	34	1.5	1
WM	67	3.0	3
S/HF	257	11.7	11.5
Surv	50	2.3	3
Comm	50	2.3	3
RGT	0		4
		26.3	**31.0**

Table 17 is the worst case schedule generated by the TE planners, and is based on Table 16 using the “Actual” column.

Table 17. TE Monthly Pessimistic Schedule

	1	2	3	4	5	6
V1	LM	LM	LM	LM	LM	F
V2	S/HF	S/HF	S/HF	S/HF	S/HF	S/HF / LM
V3	S/HF	S/HF	S/HF	S/HF	S/HF	S/HF
V4	WM	WM	WM	Comm	Comm	Comm
V5	Surv	Surv	Surv			
V6	RGT1	RGT1				
V7	RGT1	RGT1				

The TE planners assign locations after they determine the test makeup and placement on the schedule. This location assignment can vary based on available locations. Figure 12 is an example of locations that TE planners would potentially assign

based on their test venue assignment. Figure 12 is generated for comparison to the beta_max schedule generated by the model.

	1	2	3	4	5	6
V1	LM	LM	LM	LM	LM	F
V2	SH/F	SH/F	SH/F	SH/F	SH/F	SH/F / LM
V3	SHF	SH/F	SH/F	SH/F	SH/F	SH/F
V4	WM	WM	WM	Comm	Comm	Comm
V5	Surv	Surv	Surv			
V6	RGT1	RGT1				
V7	RGT1	RGT1				

Figure 12. TE Monthly Pessimistic Schedule with Test Venue Assignment

E. BEST CASE (OPTIMISTIC) SCHEDULE

Table 18 contains the beginnings of the best case schedule. The last column titled “Actual” is an adjustment made by the TE planners after the initial monthly calculation is made.

Table 18. TE Best Case Calculations

	Days	Months	Actual
LM	51	2.3	2.5
F	15	0.7	0.5
WM	29	1.3	2
S/HF	110	5.0	5
Surv	21	1.0	1
Comm	21	1.0	1
RGT	0		4
		11.2	**16.0**

The next monthly schedule that we look at is the optimistic schedule. Table 19 is the best case schedule generated by the TE planners, based on Table 18 using the “Actual” column.

Table 19. TE Monthly Optimistic Schedule

	1	2	3
V1	LM	LM	LM / F
V2	SH/F	SH/F	S/HF
V3	SH/F	SH/F	
V4	WM	WM	
V5	Surv	Comm	
V6	RGT1	RGT1	
V7	RGT1	RGT1	

The TE planners assign locations after they determine the test makeup and placement on the schedule. This location assignment can vary based on available locations. Figure 13 is an example of locations that TE planners would assign based on their test venue assignment. Figure 13 is generated for comparison to the beta_min schedule generated by the model.

	1	2	3
V1	LM	LM	LM / F
V2	SH/F	SH/F	S/HF
V3	SH/F	SH/F	
V4	WM	WM	
V5	Surv	Comm	
V6	RGT1	RGT1	
V7	RGT1	RGT1	

Figure 13. TE Monthly Optimistic Schedule with Test Venue Assignment

F. PLANNING ESTIMATE SCHEDULE

Table 20 contains the beginnings of the planning estimate schedule. The last column titled “Actual” is an adjustment made by the TE planners after the initial monthly calculation is made. Note that RGT is planned for 18 months, but only seven months go on this planning estimate schedule because the remainder is planned on the schedule after MS-C.

Table 20. TE Planning Estimate Calculations

	Days	Months	Actual
LM	77	3.5	3.5
F	22	1.0	1
WM	43	2.0	2
S/HF	164	7.5	8.5
Surv	32	1.5	2
Comm	32	1.5	1
RGT	0	18.0	7
		34.8	**25.0**

The next monthly schedule that we look at is the planning estimate schedule. Table 21 is the planning estimate schedule generated by the TE planners and is based on Table 20 using the “Actual” column.

Table 21. TE Monthly Planning Estimate Schedule

.	1	2	3	4	5
V1	LM	LM	SH/F	SH/F	SH/F
V2	SH/F	LM	SH/F/LM	SH/F	SH/F
V3	SH/F	SH/F	F		
V4	WM	WM	RGT		
V5	Surv	Surv	Comm		
V6	RGT1	RGT1	RGT2		
V7	RGT1	RGT1	RGT2		

The TE planners assign locations after they determine the test makeup and placement on the schedule. This location assignment can vary based on available locations. Figure 14 is an example of locations that TE planners would assign based on their test venue assignment. Figure 14 is generated for comparison to the beta_mean schedule generated by the model.

	1	2	3	4	5
V1	LM	LM	SH/F	SH/F	SH/F
V2	SH/F	LM	SH/F / LM	SH/F	SH/F
V3	SH/F	SH/F	F		
V4	WM	WM	RGT		
V5	Surv	Surv	Comm		
V6	RGT1	RGT1	RGT2		
V7	RGT1	RGT1	RGT2		

Figure 14. TE Monthly Planning Estimate Schedule with Test Venue Assignment

G. MODEL SCHEDULES

The five schedules that are generated by the model are based on a Monte Carlo beta distribution and consist of beta_max, beta_min, beta_mode, and beta_mean schedules. The t_periods model schedule is the 100% availability schedule, which is shorter than beta_min. The three schedules that are provided by TE are based on a Program Evaluation and Review Technique (PERT) beta distribution of pessimistic, optimistic and planning estimate. The beta_max model schedule equates to the TE planner's pessimistic schedule, and the beta_min model schedule equates to the TE planner's optimistic schedule (Edwards 2015, 6). The beta_mean model schedule equates to the TE planner's planning estimate schedule. The beta_mode schedule equates to the TE planner's most likely column from Table 14. The t_periods model schedule equates to the TE planner's "Test Days Required" 100% availability column from Table 14.

An aggregation of numbers is performed against the model run data that is similar in nature to the TE planner's efforts. Table 22 provides the number of days by CTP area for each model run schedule.

Table 22. TE Aggregated Schedule (Days) by CTP Area for the Model Run

Test	**Beta_max**	**Beta_mean**	Beta_mode	**Beta_min**	t_periods
LM	**128**	**81**	76	**55**	38
F	**34**	**23**	22	**15**	15
WM	**91**	**57**	54	**37**	27
S/HF	**582**	**394**	376	**279**	195
Surv	**50**	**32**	30	**21**	15
Comm	**50**	**33**	32	**21**	21
RGT1	88	**88**	88	88	88
RGT2	66	**66**	66	66	66

The columns that are most similar to the set of three schedules that are used by the TE planners are indicated in the Table 22 by bold text. Adding in the TE planning schedule allows comparison and is provided in Table 23.

TE schedule information contained in the tables provided in this section is based on data provided by the PM AAA TE group (Ferguson, Louis R. and Albert B. Hanneman, email message to author, April 1, 2015).

Table 23. TE Aggregated Schedule (Days) by CTP Area and Model Run Data Compared

Test	T&E Pessimistic	**Model Beta_max**	TE Planning Estimate	**Model Beta_mean**	TE Most Likely	Model Beta_mode	TE Optimistic	**Model Beta_min**	Model t_periods
LM	120	**128**	77	81	73	76	51	**55**	38
F	34	**34**	22	23	21	22	15	**15**	15
WM	67	**91**	43	57	41	54	29	**37**	27
S/HF	257	**582**	164	394	154	376	110	**279**	195
Surv	50	**50**	32	32	30	30	21	**21**	15
Comm	50	**50**	32	33	30	32	21	**21**	21
RGT1	40	88	80	88	80	88	40	88	88
RGT2	40	66	60	66	60	66	40	66	66

As can be seen in Table 23, the data that is used as input for the model run is similar, but does not exactly match, the TE planner’s data. Of particular difference are the S/HF numbers, because the S/HF numbers used in the model run include the initial inspection and safety checkout test event, which is not explicitly called out in the TE planner’s schedule. The numbers for F and Comm do not show up on the TE detailed spreadsheet given in Table 14 with numbers and “X”s in the three schedule columns. Comm and F are added as an aggregate number to each of the TE schedules after the initial detailed spreadsheet assessment. Therefore, in the model run, they are added to the input files as single test events of Comm and F.

RGT is not specifically listed by the TE planners in Table 14. RGT is something that is known and is normally added to the schedule after the rest of the test events are on the schedule. RGT is an iterative process. RGT starts with RGT1. RGT1 informs the PMO of the system reliability. Reliability improvements are incorporated through a CAP1, which is then tested as part of RGT2. RGT2 is then incorporated as part of CAP2 and is ultimately tested in Reliability Qualification Testing (RQT) to show the system reliability growth for production. RGT is incorporated into the model run by setting up seven separate test events. Four RGT test events are high priority and three RGT test events are medium priority. The four high priority RGT test events equate to RGT1 and the three medium priority test events equate to RGT2. Calculations for this particular test schedule indicate that 18 months of RGT are needed. The remaining eleven RGT months are added to the overall schedule after the milestone C event, which are tied to the end of the priority testing (after this schedule is complete).

In order to compare the model run with the TE planner schedules, the detailed daily schedules generated and shown in Appendix B are translated into monthly schedules. The daily schedules are manually generated from the model run, aggregating 20 days of the detailed daily schedules into single blocks on a MS Excel schedule. The monthly schedules are similar to what the TE planners use during the planning process. The aggregated monthly schedules are similar

to the detailed daily schedules in Appendix B in structure and colored cells, except the cells do not contain the test event identification numbers. The CTP area is used to aggregate the test events to a higher level.

H. COMPARISON OF SCHEDULES: TE PESSIMISTIC VERSUS BETA_MAX

Figure 15 is generated manually based on the detailed daily schedules given in Appendix B, Section A (Beta_max), aggregating them to a monthly schedule based on a 20 day test-month. This schedule formatting is performed for comparison to make the schedule appear in the same format as if the TE planners had developed it.

	M1	M2	M3	M4	M5	M6	M7	M8
TA1	S/HF	S/HF/LM	LM/F	F/LM	LM		WM	WM
TA2	S/HF	S/HF/LM	RGT1	LM/S/HF	LM	LM	RGT2	RGT2
TA3	S/HF	S/HF	S/HF/RGT1	RGT1/LM	LM	LM	RGT2	RGT2
TA4	S/HF	S/HF/LM	S/HF	S/HF/RGT1	RGT1/2	RGT2	LM	LM
TA5	S/HF	S/HF/Surv	Surv	Surv	Surv/S/HF	S/HF	S/HF	S/HF
TA6	S/HF	S/HF/RGT1	RGT1/WM	WM	S/HF	S/HF	S/HF	S/HF
TA7	S/HF	S/HF/WM	S/HF	WM/S/HF	WM/Comm	Comm	Comm	Comm/WM

Figure 15. Model Beta_max Monthly Schedule

The beta_max monthly schedule is aggregated from the detailed daily schedule, with test assets 1 through 7 on the y-axis (TA1 - TA7) and monthly test periods of month 1 through 8 on the x-axis (M1 - M8). The interior cells contain the test venue, indicated by cell color, and the aggregated CTP area.

As an example, test asset 3 starts out at ATC (green) in month 1 performing S/HF testing, which continues through month 2, and partially into month 3. In month 3, TA3 then moves into Reliability Growth Testing 1 (RGT1) testing, which continues into month 4. TA3 then moves into LM testing in month 4, which continues into

month 5 and month 6. In month 7, TA3 then moves into RGT2, which continues into month 8.

Before looking at the details of the differences between the Figure 12 and Figure 15 schedules, the differences between TE planner input and model input need to be understood. Table 24 shows that there is a length difference between the schedules of three months due to the difference in input data, mostly due to the added S/HF. Therefore, we cannot expect an exact match between the TE pessimistic schedule and the beta_max model schedule.

Table 24. TE versus Model Worst Case Calculations

	TE Pessimistic			Beta_max Model		
Test	Days	Months	Actual	Days	Months	Delta
LM	120	5.5	5.5	128	6.4	0.9
F	34	1.5	1	34	1.7	0.7
WM	67	3	3	91	4.6	1.6
S/HF	257	11.7	11.5	582	29.1	17.6
Surv.	50	2.3	3	50	2.5	-0.5
Comm	50	2.3	3	50	2.5	-0.5
RGT	0		4	88	7	3
		26.3	**31**		**53.8**	**22.8**

Comparing Figure 12 and Figure 15 schedules side by side, the TE pessimistic schedule and the beta_max model both have four test assets at ATC, one test asset at WSMR, and two test assets at AVTB (ignoring the first month of S/HF testing on the model schedule). The majority of testing is performed at ATC on both schedules. Land mobility, water mobility, survivability, and RGT1 CTP areas are first on both schedules (ignoring the first month of S/HF testing on the model schedule). The Comm CTP area is last on both schedules. Firepower testing happens in the middle for the model schedule and at the end of the TE planning schedule. RGT2 is at the end of the model schedule and does not exist on the TE schedule, which is due to a difference in the input data. The model

choses to go to YPG instead of ATC at the end for S/HF t41 Climatic Chambers, which is a medium priority task, whereas the TE planner's schedule uses ATC. The choice of YPG makes sense since YPG is closer to AVTB than ATC is. However, it would have made more sense to leave TA6 at AVTB and to leave TA1 at ATC instead of moving to TA1 to AVTB and TA6 to YPG. Additionally, the beta_max schedule and the detailed schedules in Appendix B, Section B (Beta_max) have some blank space in the middle, which should not be there.

When looking at these two schedules, it is apparent that the model has more overlap of CTP areas than the TE planner's schedule. The model CTP area overlap is expected since in the model generated the schedule based on the detailed test events and based on priorities and precedence. The manual aggregation to CTP area happens after the model test schedule is generated. The TE planners add the CTP areas together before the schedule is generated. As expected, the model input does not completely match what is used for the TE planners, which makes the beta_max schedule three months longer than the TE pessimistic schedule. In spite of these differences, overall, the model beta_max schedule is a reasonable schedule option.

I. COMPARISON OF SCHEDULES: TE OPTIMISTIC VERSUS BETA_MIN

Figure 16 is generated manually based on the detailed daily schedules in Appendix B, Section C (Beta_min), aggregating them to a monthly schedule based on a 20 day test-month. This schedule formatting is performed for comparison to make the schedule appear in the same format as if the TE planners had developed it.

	M1	M2	M3	M4
TA1	S/HF/LM	S/HF/LM/R GT1	RGT1/2	RGT2/LM
TA2	S/HF/LM	LM/F	LM/S/HF	SHF/LM
TA3	S/HF	RGT1	S/HF	LM
TA4	S/HF/RGT1	RGT1/LM	LM/S/HF	S/HF
TA5	S/HF	Surv	RGT2	RGT2
TA6	S/HF	WM	WM/Comm	Comm/WM
TA7	S/HF/RGT1	RGT1/WM	S/HF/RGT2	RGT2/WM

Figure 16. Model Beta_min Monthly Schedule

The beta_min monthly schedule is aggregated from the Appendix B daily schedules, with test assets TA1 - TA7 on the y-axis and monthly test periods M1 - M4 on the x-axis. The interior cells contain test venue, indicated by cell color, and the aggregated CTP areas.

As an example, TA3 starts out at ATC (green) in month 1, performing S/HF testing. TA3 remains at ATC and moves into RGT1 in month 2. TA3 moves into S/HF testing in month 3. TA3 then moves into LM testing in month 4.

Before looking at the details of the differences between the Figure 13 and the Figure 16 schedules, the differences between TE planner input and model input need to be understood. Table 25 shows that there is a length difference between the schedules of two months due to the difference in input data, mostly due to the added S/HF. Therefore, we cannot expect an exact match between the TE optimistic schedule and the beta_min model schedule.

Table 25. TE Optimistic versus Model Beta_min Calculations

	Optimistic			**Beta_min Model**		
	Days	Months	Actual	Days	Months	Delta
LM	51	2.8	2.5	55	2.8	0.3
F	15	0.8	0.5	15	0.8	0.3
WM	29	1.9	2	37	1.9	-0.1
S/HF	110	14.0	5	279	14.0	9.0
Surv.	21	1.1	1	21	1.1	0.1
Comm	21	1.1	1	21	1.1	0.1
RGT	0	7.7	4	154	7.7	3.7
		29.1	**16.0**		**29.1**	13.1

Comparing Figure 13 and Figure 16 side by side, the TE optimistic schedule and the beta_min model schedule both start with four test assets at ATC, one test asset at WSMR, and two test assets at AVTB (ignoring the first month of S/HF testing on the model schedule). Land mobility, water mobility, survivability, and RGT1 CTP areas are first on both schedules (ignoring the first month of S/HF testing on the model schedule). The Comm CTP area is last on both schedules. Firepower testing happens in the middle for the model schedule and at the end of the TE planning schedule. RGT2 testing is at the end of the model schedule and does not exist on the TE schedule, which is due to a difference in the input. The beta_min schedule has some blank spaces here and there in the middle of the detailed schedules in Appendix B, Section D (Beta_min), which should not be there

When looking at these two schedules, it is apparent that the model has more overlap of CTP areas than the TE planner's schedule. The model CTP area overlap is expected because the model generated the schedule based on the detailed test events and based on priorities and precedence. The manual aggregation to CTP area happens after the model test schedule is generated. The TE planners add the CTP areas together before the schedule is generated. As expected, the model input does not completely match what is used for the TE planners, which makes the beta_min schedule two months longer than the TE

optimistic schedule. The model schedule is more accurate relative to test event priorities and places the medium priority tasks at the end. This approach is in conflict with the approach of aggregating to CTP area before putting it on the schedule as the TE planners do. In spite of these differences, overall, the model beta_min schedule is a reasonable schedule option.

J. COMPARISON OF SCHEDULES: TE PLANNING ESTIMATE VERSUS BETA_MEAN

Figure 17 is generated manually based on the detailed daily schedules in Appendix B, Section E (Beta_mean), aggregating them to a monthly schedule based on a 20 day test-month. This schedule formatting is performed for comparison to make the schedule appear in the same format as if the TE planners had developed it.

	M1	M2	M3	M4	M5	M6
TA1	S/HF	LM	LM/S/HF	S/HF/LM	LM	
TA2	S/HF	S/HF/F	F/S/HF	S/HF	S/HF	S/HF
TA3	S/HF	RGT1	RGT1/LM	RGT1/2	RGT2/LM	
TA4	S/HF	RGT1	RGT1/LM/S/HF	S/HF/LM	RGT2	
TA5	S/HF	Surv	Surv	S/HF	S/HF	S/HF
TA6	S/HF	S/HF/WM	WM	WM	RGT2	RGT2/WM
TA7	S/HF	RGT1	RGT1/WM/S/HF	WM/Comm	Comm	Comm/WM

Figure 17. Model Beta_mean Monthly Schedule

The beta_mean monthly schedule is aggregated from the daily Appendix B schedule, with test assets TA1 – TA7 on the y-axis and monthly test periods M1 - M6 on the x-axis. The interior cells contain test venue, indicated by cell color, and the aggregated CTP areas.

As an example, test asset 2 starts out at ATC (green) in month 1, performing S/HF testing. TA2 remains at ATC in month 2, continues S/HF testing, and transitions into F testing at the end of month 2. In month 3, TA2

continues F testing and transitions into S/HF testing. TA2 continues S/HF testing for months 4, 5, and 6.

Before looking at the details of the differences between the Figure 14 and Figure 17 schedules, the differences between TE planner input and model input need to be understood. Table 26 shows that there is a length difference of two months due to the difference in input data. Therefore, we cannot expect an exact match between the TE planning estimate schedule and the beta_mean model schedule.

Table 26. TE Planning Estimate versus Model Beta_mean Calculations

	TE Planning Estimate			**Beta_mean Model**		
	Days	Months	Actual	Days	Months	Delta
LM	77	3.5	3.5	81	4.1	0.6
F	22	1.0	1	23	1.2	0.2
WM	43	2.0	2	57	2.9	0.9
S/HF	164	7.5	8.5	394	19.7	11.2
Surv.	32	1.5	2	32	1.6	-0.4
Comm	32	1.5	1	33	1.7	0.7
RGT	0	18.0	7	154	7.7	0.7
		34.8	**25.0**		**38.9**	13.9

Comparing Figure 14 and Figure 17 side by side, the TE schedule has three test assets at ATC, whereas the beta_mean has four test assets at ATC. The TE schedule has three test assets at AVTB, whereas the beta_mean has two test assets at AVTB. Both schedules have one test asset at WSMR. Land mobility, water mobility, S/HF, survivability, and RGT1 are first (after the S/HF that is added at the beginning of the beta-mean schedule). The Comm CTP area is last on both schedules. The beta_mean schedule does move a test asset to YTC after WSMR. This test venue movement makes sense because YTC is closer than ATC. In contrast, a test planner might chose ATC or AVTB instead because vehicles are then at less test venues.

When looking at these two schedules, it is apparent that the model has more overlap of CTP areas than the TE planner's schedule. The model CTP area overlap is expected because the model generated the schedule based on the detailed test events and based on priorities and precedence. The manual aggregation to CTP area happens after the model test schedule is generated. The TE planners add the CTP areas together before the schedule is generated. As expected, the model input does not completely match what is used for the TE planners, which makes the beta_mean schedule two months longer than the TE planning estimate schedule. The model schedule is more accurate relative to test event priorities and places the medium priority tasks at the end. This approach is in conflict with the approach of aggregating to CTP area before putting it on the schedule as the TE planners do. In spite of these differences, overall, the model beta_mean schedule is a reasonable schedule option.

K. COMPARISON OF SCHEDULES: TE PLANNING ESTIMATE VERSUS BETA_MODE

Figure 18 is generated manually based on the detailed schedules in Appendix B, Section D (Beta_mode), aggregating them to a monthly schedule based on a 20 day test-month. This schedule formatting is performed to make the schedule appear in the same format as if the TE planners had developed it. Beta_mode testing equates to the most likely testing column in Table 15.

	M1	M2	M3	M4	M5	M6
TA1	S/HF	LM	LM/S/HF	S/HF	S/HF	
TA2	S/HF	S/HF/WM	S/HF/RGT1	RGT2	RGT2/WM	WM
TA3	S/HF	S/HF	F	LM	LM	LM
TA4	S/HF	RGT1	S/HF/LM	LM	RGT2	RGT2
TA5	S/HF	Surv	Surv/S/HF	S/HF	S/HF	
TA6	S/HF	RGT1	WM	WM/Comm	Comm	Comm
TA7	S/HF	RGT1	S/HF/WM	WM/RGT2	RGT2/WM	WM

Figure 18. Model Beta_mode Monthly Schedule

The beta_mode monthly schedule is aggregated from the daily test periods schedule, with test assets TA1 - TA7 on the y-axis and monthly test periods M1 - M6 on the x-axis. The interior cells contain test venue, indicated by cell color (AVTB = blue, ATC = green, YPG = purple, and WSMR = salmon), and the aggregated CTP areas. For example, TA5 starts out at WSMR (salmon) in month 1, performing S/HF testing. In month 2, TA5 remains at WSMR and moves into Survivability (Surv) testing in month 2, which continues into month 3. Partway through month 3, TA5 moves into S/HF testing. In month 4, TA5 moves to YPG (purple) and performs S/HF testing into month 5, where TA5 testing is complete.

Before looking at the details of the differences between the Figure 14 and Figure 18 schedules, the differences between TE planner input and model input need to be understood. Table 27 shows that there is a length difference of two months due to the difference in input data. Therefore, we cannot expect an exact match between the TE planning estimate schedule and the beta_mode model schedule.

Table 27. TE Planning Estimate versus Model Beta_mode Calculations

	TE Planning Estimate			**Beta_mode Model**		
	Days	Months	Actual	Days	Months	Delta
LM	77	3.5	3.5	76	3.8	0.3
F	22	1.0	1	22	1.1	0.1
WM	43	2.0	2	54	2.7	0.7
S/HF	164	7.5	8.5	376	18.8	10.3
Surv.	32	1.5	2	30	1.5	-0.5
Comm	32	1.5	1	32	1.6	0.6
RGT	0	18.0	7	88	7.7	3.7
		34.8	**25.0**		**37.8**	15.2

While beta_mode is not expected to exactly track to the TE planning estimate schedule, they are the closest for comparison purposes. When

comparing Figure 14 to Figure 18, as expected, the model input does not completely match what is used by the TE planners, and is longer. Therefore, we cannot expect an exact match between the two schedules. Month 6 has so few entries, that we could actually delete month 6 from the beta_mode schedule.

Comparing Figure 14 and Figure 18 side by side, both schedules have three test assets at ATC, three test assets at AVTB, and one test asset at WSMR (ignoring the first month of S/HF testing on the model schedule). Land mobility, water mobility, S/HF, survivability, and RGT1 are first (ignoring the first month of S/HF testing on the model schedule). The Comm CTP area is last on both schedules. The beta_mode schedule does move a test asset to YTC after WSMR. This test venue movement makes sense because it is closer than ATC, whereas a test planner might chose ATC or AVTB instead because vehicles are then at less test venues.

When looking at these two schedules, it is apparent that the model has more overlap of CTP areas than the TE planner's schedule. The model CTP area overlap is expected because the model generated the schedule based on the detailed test events based on priorities and precedence. The manual aggregation to CTP area happens after the test schedule is generated. The TE planners add the CTP areas together before the schedule is generated. As expected, the model input does not completely match what is used for the TE planners, which makes the beta_mode schedule two months longer than the TE optimistic schedule. The model schedule is more accurate relative to test event priorities and places the medium priority tasks at the end. This approach is in conflict with the approach of aggregating to CTP area before putting on the schedule, as the TE planners do. In spite of these differences, overall, the model beta_mode schedule is a reasonable schedule option.

L. COMPARISON OF SCHEDULES : TE PLANNING ESTIMATE VERSUS T_ PERIODS

Figure 19 is generated manually based on the detailed schedules in Appendix B, Section B (t_periods), aggregating them to a monthly schedule based on a 20 day test-month. This schedule formatting is performed to make the schedule appear in the same format as if the TE planners had developed it. Testing schedule t_periods equates to the test days required column in Table 14.

	M1	M2	M3	M4
TA1	S/HF/Surv	Surv/LM	LM	
TA2	S/HF/LM	LM/S/HF	LM/S/HF	S/HF
TA3	S/HF/LM	RGT1	LM/RGT1	RGT1
TA4	S/HF/F	F/S/HF/LM	S/HF	S/HF
TA5	S/HF/WM	WM	RGT2	RGT2/WM
TA6	S/HF	WM/RGT1	RGT1/Comm	Comm
TA7	S/HF/RGT1	RGT1/2	RGT2	WM

Figure 19. Model t_periods Monthly Schedule

This monthly schedule is aggregated from the daily test periods schedule, with test assets TA1 - TA7 on the y-axis and monthly test periods M1 - M4 on the x-axis. The interior cells contain test venues indicated by cell color and the aggregated CTP areas. For example, TA6 starts out at AVTB (blue) in month 1, performing S/HF testing. TA6 remains at AVTB and moves into water mobility testing in month 2 but moves into RGT1 partway through month 2. TA6 continues RGT1 testing in month 3 and transitions into Comm testing in month 3, continuing through month 4.

Before looking at the details of the differences in the actual schedules, the differences between TE planner input and model input need to be understood. Table 28 shows the input data differences between Figure 14 and Figure 19.

Table 28 shows that there is little overall length difference between the planning estimate and the t_periods due to the difference in input data, although there are specific differences in CTP area numbers. For example, LM CTP area is 3.5 months for the TE planning estimate schedule, whereas the t_periods LM CTP area is 1.9 months, which gives a delta of 1.6 months.

Table 28. TE Planning Estimate versus Model t_periods Calculations

CTP Area	**TE Planning Estimate**			**t_periods Model**		
	Days	Months	Actual	Days	Months	Delta
LM	77	3.5	3.5	38	1.9	1.6
F	22	1.0	1	15	0.8	0.3
WM	43	2.0	2	27	1.4	0.7
S/HF	164	7.5	8.5	195	9.8	-1.3
Surv.	32	1.5	2	15	0.8	1.3
Comm	32	1.5	1	21	1.1	-0.1
RGT	0	18.0	7	154	7.7	-3.7
		34.8	**25.0**		**23.5**	-1.3

Although the TE planning estimate schedule and the t_periods model schedule have the closest schedule data for comparison purposes, they are not expected to track to each other exactly. Therefore, when comparing Figure 14 to Figure 19, we do not expect an exact match between the two schedules.

Comparing Figure 14 and Figure 19 side by side, the TE schedule initially has three test assets at ATC, one test asset at WSMR, and three test assets at AVTB, whereas the t_periods model schedule initially has four test assets at ATC and AVTB and one at WSMR. In the second month, however, the schedules track to the same locations. There is a starting location that is a model input that caused this initial location difference. Additionally, land mobility, water mobility, survivability and RGT1 are the first CTP areas (after the S/HF that is added at the beginning of the t_periods schedule). The Comm CTP area is last on both schedules. RGT1 occurs at the beginning of the schedule, and RGT2 occurs at

the end of both schedules. One difference between the two schedules is F is earlier on the model schedule and later on the TE schedule.

When looking at these two schedules, it is apparent that the model has more overlap of CTP areas than the TE planner's schedule. The model CTP area overlap is expected because in the model generated the schedule based on the detailed test events and based on priorities and precedence. The manual aggregation to CTP area happens after the model test schedule is generated. The TE planners add the CTP areas together before the schedule is generated. As expected, the model input does not completely match what is used for the TE planners, although it is close. The model schedule is more accurate relative to test event priorities and places the medium priority tasks at the end. This approach is in conflict with the approach of aggregating to CTP area before putting it on the schedule as the TE planners do. In spite of these differences, overall, the model t_periods schedule is a reasonable schedule option.

The actual schedule used by TE for this program is given in Figure 20. The Figure 20 schedule tracks to the planning estimate schedule, with insertion of the CAP period, the OA, and the additional eleven months of RGT.

	1	2	3	4	5	6	7
V1	LM	S/HF	S/HF	CAP[1]	LM	S/HF	RGT
V2	S/HF	LM	S/HF & LM	CAP[1]	S/HF	S/HF	RGT
V3	S/HF	S/HF	Firepower	CAP[1]	RGT[2]	RGT	RGT
V4	WM	WM	RGT[2]	CAP[1]	RGT[2]	RGT	RGT
V5	Surv	Surv	Comm	CAP[1]	RGT[2]	OA event	
V6	RGT[1]	RGT[1]	RGT[2]	CAP[1]	RGT		
V7	RGT[1]	RGT[1]	RGT[2]	CAP[1]	RGT		

Figure 20. TE Planning Schedule Used

M. MODEL VALIDATION SYNOPSIS

By looking at all of the schedules and the comparison data, the model is assessed against the Table 1 operational needs from a validation perspective in Table 29. When assessing from this perspective, the only options are MET, NOT MET, and NOT VALIDATED.

Table 29. Operational Needs and Model Verification Results

Need #	Title	Tier	Operational Needs	Model Verification Assessment	Model Validation Assessment
N1	Multiple Asset Types (O)	APA	The TE RSCSP model low priority test events shall be allowed to go beyond the test period.	NOT VERIFIED	NOT VALIDATED. Test data is insufficient to answer the question, although the model has the ability. Additional model runs and verification efforts would be beneficial.
N2	Multiple Assets (T=O)	KSA	The TE RSCSP model shall allow multiple test assets to be tested simultaneously.	PARTIALLY MET	MET. While multiple test assets are tested simultaneously, multiple test asset types (O) have not been verified. Additional model runs and verification efforts would be beneficial.
N3	Time Period Asset Availability (O)	APA	The TE RSCSP model shall have a time period test asset availability constraint.	NOT VERIFIED	NOT VALIDATED. Test data insufficient to answer the question, although the model has the ability. Additional model runs and verification efforts would be beneficial.
N4	Venue Distance (T=O)	KSA	The TE RSCSP model shall minimize test movement between test venues.	MET	MET. The model minimized movement between test venues.

Need #	Title	Tier	Operational Needs	Model Verification Assessment	Model Validation Assessment
N5	Event Priority Placement (T=O)	KSA	The TE RSCSP model shall place test events based on priority.	PARTIALLY MET	MET. The model is doing a good job of placing test events based on priority, Additional model runs and verification efforts would be beneficial.
N6	Multiple Venues (T=O)	APA	The TE RSCSP model shall allow multiple test venues to be used at the same time.	MET	MET. Multiple test venues are used at the same time.
N7	Venue Choice by Event (T=O)	APA	The TE RSCSP model shall allow test venue choice by test event.	MET	MET. Test venues are chosen by test event, with multiple options available.
N8	Multiple Events (T=O)	APA	The TE RSCSP model shall allow multiple test events to occur at the same time.	MET	MET. The test schedules show that multiple test events happen at the same time, and the model allows test events to occur on multiple test assets simultaneously.
N9	Precedence Relationship (T=O)	APA	The TE RSCSP model shall have test event predecessor and successor relationship constraints.	MET	MET. Test event predecessor and successor relationships are successful.
N10	Deadline for each Priority (T=O)	APA	The TE RSCSP model shall place test assets based on a deadline for each priority type.	PARTIALLY MET	MET. Additional model runs and verification efforts would be beneficial for deadlines not currently verified.

Need #	Title	Tier	Operational Needs	Model Verification Assessment	Model Validation Assessment
N11	Schedule Test Events (T=O)	KPP	The TE RSCSP model shall minimize the time period used for test events.	MET	MET. Additional model runs and verification efforts would be beneficial. While there are some blanks in the beta_max schedule, the blanks are believed to be due to the shortening of the time to run the model.
N12	MS Excel Input (T=O)	APA	The TE RSCSP model shall allow TE personnel to input information in MS Excel.	PARTIALLY MET	MET. While the current approach is not ideal, the approach is acceptable. The MS Excel input approach is an area that can be improved upon.
N13	MS Excel Output (T=O)	KPP	The TE RSCSP model shall output schedules in a MS Excel Format showing each vehicle, using colors for test site, and using blocks that aggregate the information into the month.	NOT MET	NOT MET. This is an area that can be improved upon.
N14	Model in MS Excel (O)	APA	The TE RSCSP model shall use MS Excel only. This means that a specialized tool will not be used for the model.	NOT MET	NOT MET. The use of a specialized tool is an area that can be improved upon.

OT validation assessment of the capabilities results follow:

- One of two KPP is assessed as MET.
- Three of three KSAs are assessed as MET.
- Six of six Threshold = Objective APAs are assessed as MET.
- Zero of three Objective APAs are assessed as MET

The majority of the capabilities requested for the model are assessed as MET. Discussions follow of the ones that are not assessed as MET:

The “MS Excel Output (T=O)” KPP is NOT MET since the model is not displayed in MS Excel using the format that the TE personnel currently use. This issue could potentially be addressed by writing code in MS Excel that would convert the data from the model output and display the GAMS output in a format similar to the one that the test planner’s use.

The “Time Period Asset Availability (O)” APA, which allows for test assets to be assigned as unavailable during a test period, is NOT VALIDATED. The model problem formulation and the model input files show that the model appears to support this APA, but the model has not been tested.

The “Multiple Asset Types (O)” APA, which allows low priority test events to go beyond the test period, is NOT VALIDATED. The model problem formulation and the model input files show that the model appears to support this APA, but the model has not been tested.

The “Model in MS Excel (O)” APA, which requires the use of MS Excel as the tool to perform this modelling, is NOT MET. The model uses GAMS with CMPLX solver as the modeling tool.

N. MODEL CRITICAL OPERATIONAL ISSUES

This research explores whether optimization can aid in the test schedule development process. Five model schedules have been evaluated against the

requirements and against TE schedules. The three research questions addressed by this thesis, considered as COIs, are now assessed:

a. Can a test scheduling model automate the test schedule development process? As illustrated in Table 29, all threshold capabilities are met, except for one KPP relative to schedule output. The model generates a computer printout, as shown in Figure 10. In order to complete the test schedule development process, the model output must be manually converted into detailed schedules and then into aggregated schedules. Without achieving this KPP, the model cannot be considered to be "automated" without additional work. However, the additional post-processing automation that would be needed is achievable. Therefore, we can state that a test scheduling model can automate the test schedule development process, and we have assessed this COI as MET.

b. Can a test scheduling model optimize the PMO test scheduling activity to provide multiple optimized test schedule options? The model uses five schedule sets of information based on the spreadsheet that the TE planners provided. The model produces a printout, as shown in Figure 10. The model output contains detailed information for five schedules, which are shown for this model run in Appendix B. The model provides detailed daily schedules instead of monthly schedules based on aggregated data. Aggregation of data from the daily level to the monthly level is something that can be achieved. As stated in the first COI, the post-processing to provide the data in the TE format is achievable. Therefore, we can state that a test scheduling model can optimize test scheduling by providing multiple optimized schedules, and we have assessed this COI as MET.

c. Can a test scheduling model determine the best PMO schedule mix of test assets and test facilities? The detailed schedules produced track to the constraints and decision rules from the problem statement and requirements. The detailed model schedules produced by the model and contained in Appendix B were reasonable detailed schedules. A couple of the longer schedules generated had empty cells in the middle, but the blocks could be easily shifted to

the left with additional post-processing. The model provides detailed daily schedules instead of monthly schedules based on aggregated data. Aggregation of data from the daily level to the monthly level is something that could be accomplished. As stated in the first COI, the post-processing to provide the data in the TE format is achievable. The evaluations in this thesis show that a test scheduling model can determine the mix of test assets and test facilities and have assessed this COI as MET.

As discussed in the COIs, while the model itself performed well, the model output required manual conversion into the TE planners schedule format. The time required to convert the data from the current model form into a useful schedule is such that the model is not operationally effective, nor is the model operationally suitable in its current form. Additional work is needed in the area of model output before the model would be considered to be operationally effective and operationally suitable.

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VI. CONCLUSION

Test schedule development is a specialized process that is complex, time-consuming, and iterative. The methodology used for test schedule development depends on the individual test planner and is based on heuristics.

This research establishes the heuristic test schedule development process, and develops COIs, operational needs, and detailed requirements for a test scheduling model using constraint and rule-based optimization. The resulting model (Edwards 2015) is assessed against the requirements, operational needs, and COIs.

Results of this research show that the optimization model developed by Shane Edwards (Edwards 2015) meets one of two KPPs, all of the KSAs, and the threshold APA requirements. The model achieves the following:

- provides schedules that are reasonably close to what the TE planners would use
- minimizes test movement between test venues and uses a test venue distance constraint
- allows multiple test assets to be tested simultaneously
- places test events based on priority
- allows multiple test venues to be used at the same time
- allows test venue choice by test event
- allows multiple test events to occur at the same time
- has test event predecessor and successor relationship constraints
- places test assets based on a deadline for each priority type
- minimizes the time period used for test events
- allows TE personnel to enter input information in MS Excel

Although the model meets the majority of the requirements, the results of this research indicate that the model it is not operationally effective, nor is it operationally suitable due to failure to meet the output KPP. However, with additional work to display the output differently, the TE test schedule optimization model would be a good tool for the TE schedulers to use to improve PMO test schedule development.

A. FURTHER RESEARCH

Further research could mature the model in the areas of additional functionality, model performance, ease of use, and incorporation into PMO tools, as identified by the model developer (Edwards 2015).

Further research could mature the model to add RGT to the model. Although RGT is included in model test events, RGT is a completely different type of testing that has special calculations and rules. The current model could be enhanced by incorporating these RGT calculation and rules instead of requiring this activity to be performed outside of the model.

Further research could extend the model to address the entire PMO schedule, not just the TE portion. A PMO schedule model would benefit PMOs since PMOs continuously re-plan, with many variables in play. A tool to help make PMO decisions would therefore be beneficial.

APPENDIX A. MODEL INPUT AND OUTPUT

The input for the model contains multiple input files that result in multiple schedule outputs in a single file. Included in this appendix are data input files and the output file used as examples to verify the model. All of these files are provided by Shane A. Edwards (2015), the model developer. All tables in this appendix are based on Shane Edwards model input files (email message to author, June 12, 2015).

A. INPUT

The model input consists of many files identified as follows:

a. Model variable p. The set of time periods that the test assets can be assigned to test venues (v) is identified in this file (p.csv) and is shown in Table 30. This time period is available to each test asset, assuming that the test asset is available for testing. This time period set can be exceeded for low priority tests.

Table 30. Test Period

```
{ set p time periods }
p001*p190
```

b. Model variable t. The tests that need to be performed by the test assets are located in this file (t.csv), and are given in Tables 31.

Table 31. Test Events

```
{ set t tasks plus explanatory text}
t01 Tilt Table
t02 Side Slopes
t03 Standard Obstacles
t04 Land Mode Braking
t05 Controlled Maneuverability
t06 Acceleration Max. and Min. Speeds
```

{ set t tasks plus explanatory text}
t07 Land Mobility Towing
t08 Longitudinal Slopes
t09 Drawbar Pull and Cooling System Heat Balance
t10 Dead Engine Braking
t11 Rolling Resistance
t12 Fuel Consumption_land
t13 Initial Inspection and Safety Checkout ATVB_CA
t14 Fuel Consumption_amphibious
t15 Plow in testing
t16 Controlled Maneuverability
t17 Speed and Powering
t18 Maximum Gross Vehicle Weight
t19 Line Passing and Towing
t20 Surf Transit
t22 Ship Operations
t23 Multi_vehicle operations
t24 Navigation and Obstacle Avoidance
t25 Initial Inspection and Safety Checkout ATC_MD
t27 Land Mode Ingress_Egress
t28 Land Mode Ride Quality
t29 Land Mode Interior Noise and Whole Body Vibration
t33 Emergency Egress land and water
t36 Land Mode Automotive Toxic Fumes
t37 Automotive Toxic Fumes in Water
t39 Transportability
t40 Physical Characteristics
t41 Climatic Chambers
t53 E3 testing_limited
t56 RGT
t57 RGT
t58 RGT
t59 RGT
t60 RGT
t61 RGT
t62 RGT
t63 Communications
t64 Firing

c. Model variable a. The set of test asset types that are being tested are located in this file (a.csv), and are shown in Table 32. In this particular example, there is only one asset type identified as AAV.

Table 32. Test Asset Types

```
{ set a asset types }
AAV
```

d. Model variable v. The test facility venues are located in this file (v.csv), and are shown in Table 33. Although test venues are identified in this file, these test facility venues may or may not be used because use depends on the association of the test venue to the test event and if the model choses the test venue.

Table 33. Test Venues

```
ATC_MD
AVTB_CA
EPG_AZ
WSMR_NM
YPG_AZ
DPG_UT
```

e. Model variable i. The ordered set of priorities that test events can be set to is located in this file (i.csv), and is shown in Table 34.

Table 34. Test Event Priorities

```
{ set i priorities ordered }
 high
 medium
 low
```

f. Model variable relationships m_periods. The time periods needed to move between the test venues for all combinations is located in this file (m_periods.csv), and is shown in Table 35. These time periods are inserted into the test schedule when the model makes the decision to move test assets to test venues (v). The first column is the test venue from location, the second column is the test venue to location, and the last column is the number of time periods needed to move to the test venue.

Table 35. Test Venue Movement Time Periods

dummy	dummy	m_periods
{ TABLE m_periods(v vp) }		{ upper diagonal only assumed symmetric }
ATC_MD	AVTB_CA	6
ATC_MD	EPG_AZ	5
ATC_MD	WSMR_NM	5
ATC_MD	YPG_AZ	5
ATC_MD	DPG_UT	5
AVTB_CA	EPG_AZ	6
AVTB_CA	WSMR_NM	3
WSMR_NM	YPG_AZ	3
WSMR_NM	DPG_UT	3
WSMR_NM	ATC_MD	5
YPG_AZ	AVTB_CA	3
YPG_AZ	EPG_AZ	3
YPG_AZ	WSMR_NM	3
YPG_AZ	DPG_UT	3
YPG_AZ	ATC_MD	5
DPG_UT	AVTB_CA	3
DPG_UT	EPG_AZ	3
DPG_UT	WSMR_NM	3
DPG_UT	YPG_AZ	3
DPG_UT	ATC_MD	5

g. Model variable v_cap. The number of test assets that each test facility venue can accommodate is located in this file (v_cap), and is shown in Table 36. The first column is the test facility venue and the second is the test asset capacity.

Table 36. Test Venue Test Asset Capacity

ATC_MD	10
AVTB_CA	10
EPG_AZ	10
WSMR_NM	10
YPG_AZ	10
DPG_UT	10

h. Model variable relationships ti. The priorities (i) of the individual test events (t) relationships are identified in this file (ti.csv), and are shown in Table 37. The first column is the test event and the second is the associated priority.

Table 37. Test Event Priority Relationships

t01	high
t02	high
t03	high
t04	high
t05	high
t06	high
t07	medium
t08	high
t09	medium
t10	high
t11	medium
t12	high
t13	high
t14	high
t15	high
t16	high
t17	high
t18	high
t19	high
t20	high
t22	high
t23	medium
t24	medium
t25	high
t27	high
t28	high
t29	high
t33	high
t36	high
t37	high
t39	medium
t40	medium
t41	medium
t53	medium
t56	high
t57	high

t58	high
t59	high
t60	medium
t61	medium
t62	medium
t63	medium
t64	high

i. Model variable relationship vt. This file identifies the test locations that can perform each test, and is shown in Table 38. The first column is the test location venue (v). The second column is the test event (t) identified by txx where xx is the number of the test as identified in Table 31. The third column identifies the test asset type that the test is to be performed on. This particular file has only one type.

There are five venues identified as ATC_MD, AVTB_CA, WSMR_NM, YPG_AZ, DPC_UT, and EPG_AZ. In this input file, there are some instances where multiple test venues are identified as potential test venues for a test event.

Table 38. Test Event Test Venue Relationships

{ SET vt(vt) facilities capable of performing each test }

{ vt pairs intentionally omitted as test }

ATC_MD	t01	1
ATC_MD	t02	1
ATC_MD	t03	1
ATC_MD	t04	1
ATC_MD	t05	1
ATC_MD	t06	1
ATC_MD	t07	1
ATC_MD	t08	1
ATC_MD	t09	1
ATC_MD	t10	1
ATC_MD	t11	1
ATC_MD	t12	1
AVTB_CA	t13	1
AVTB_CA	t14	1
AVTB_CA	t15	1

{ SET vt(vt) facilities capable of performing each test }

{ vt pairs intentionally omitted as test }

AVTB_CA	t16	1
AVTB_CA	t17	1
AVTB_CA	t18	1
AVTB_CA	t19	1
AVTB_CA	t20	1
AVTB_CA	t22	1
AVTB_CA	t23	1
AVTB_CA	t24	1
ATC_MD	t25	1
ATC_MD	t27	1
ATC_MD	t28	1
ATC_MD	t29	1
AVTB_CA	t33	1
ATC_MD	t36	1
AVTB_CA	t37	1
ATC_MD	t39	1
ATC_MD	t40	1
ATC_MD	t41	1
YPG_AZ	t41	1
WSMR_NM	t53	1
ATC_MD	t56	1
AVTB_CA	t56	1
WSMR_NM	t56	1
YPG_AZ	t56	1
ATC_MD	t57	1
AVTB_CA	t57	1
WSMR_NM	t57	1
YPG_AZ	t57	1
ATC_MD	t58	1
AVTB_CA	t58	1
WSMR_NM	t58	1
YPG_AZ	t58	1
ATC_MD	t59	1
AVTB_CA	t59	1
WSMR_NM	t59	1
YPG_AZ	t59	1
ATC_MD	t60	1
AVTB_CA	t60	1
WSMR_NM	t60	1
AVTB_CA	t60	1
WSMR_NM	t60	1
YPG_AZ	t60	1

{ SET vt(vt) facilities capable of performing each test }		
	{ vt pairs intentionally omitted as test }	
ATC_MD	t61	1
AVTB_CA	t61	1
WSMR_NM	t61	1
YPG_AZ	t61	1
ATC_MD	t62	1
AVTB_CA	t62	1
WSMR_NM	t62	1
YPG_AZ	t62	1
AVTB_CA	t63	1
ATC_MD	t64	1

j. Model variable relationship rt. The set of test event precedence relationships (t, tp) are located in this file (rt.csv), and are shown in Table 39. The first column is the predecessor test event and the second column is the successor test event.

Table 39. Test Event Precedence Relationships

{ SET rt(t	tp) precedence test t must finish before test tp starts }
t01	t02
t11	t09
t13	t14
t13	t15
t13	t16
t13	t17
t13	t18
t13	t19
t13	t20
t13	t22
t13	t23
t13	t24
t13	t63
t15	t16
t15	t17
t15	t18
t25	t01
t25	t02
t25	t03

{ SET rt(t tp) precedence test t must finish before test tp starts }

t25	t04
t25	t05
t25	t06
t25	t07
t25	t08
t25	t09
t25	t10
t25	t11
t25	t12
t25	t14
t25	t15
t25	t16
t25	t17
t25	t18
t25	t19
t25	t20
t25	t22
t25	t23
t25	t24
t25	t27
t25	t28
t25	t29
t25	t33
t25	t36
t25	t37
t25	t39
t25	t40
t25	t41
t25	t53
t25	t64
t40	t39
t53	t22

k. Model variable relationship t_data. The identification of how many test assets are needed simultaneously for each test event and how many test periods are required for each test event is located in this file (t_data.csv), and is shown in Table 40. The information is given for four different input amounts for the number of test periods needed and number of test assets needed for each test event (t_periods, min, mode, and max). The first column is the test event. The second

column is the number of test assets needed to execute the test event. The third column identifies the number of test periods needed for the test event for the t_periods schedule. The fourth column identifies the number of test periods needed for the test event for the beta_min schedule. The fifth column identifies the number of test periods needed for the test event for the beta_mode schedule. The sixth column identifies the number of test periods needed for the test event for the beta_max schedule.

Table 40. Test Event Test Period Durations and Number of Test Assets Needed for Test Events

{ t_data(t	vehicles	t_period	min	mode	max}
t01	1	1	1	2	3
t02	1	2	3	4	7
t03	1	4	6	8	13
t04	1	2	3	4	7
t05	1	2	3	4	7
t06	1	2	3	4	7
t07	2	2	3	4	7
t08	1	3	4	6	10
t09	1	10	14	20	33
t10	1	2	3	4	7
t11	1	2	3	4	7
t12	1	4	6	8	13
t13	3	9	13	18	30
t14	1	5	7	10	17
t15	1	2	3	4	7
t16	1	2	3	4	7
t17	1	2	3	4	7
t18	1	2	3	4	7
t19	2	1	1	2	3
t20	1	1	1	2	3
t22	1	2	3	4	7
t23	2	3	4	6	10
t24	1	3	4	6	10
t25	4	9	13	18	30
t27	1	1	1	2	3
t28	1	5	7	10	17
t29	1	5	7	10	17
t33	1	2	3	4	7

{ t_data(t	vehicles	t_period	min	mode	max}
t36	1	5	7	10	17
t37	1	5	7	10	17
t39	1	20	29	40	67
t40	1	5	7	10	17
t41	1	20	29	40	67
t53	1	15	21	30	50
t56	1	22	22	22	22
t57	1	22	22	22	22
t58	1	22	22	22	22
t59	1	22	22	22	22
t60	1	22	22	22	22
t61	1	22	22	22	22
t62	1	22	22	22	22
t63	1	21	21	32	50
t64	1	15	15	22	34

l. Model variable relationship ta_data. This file identifies the test locations that can perform each test (ta_data.csv), and is shown in Table 41. The first column is the test event. The second column is the test asset type. The third column identifies whether or not the test asset is subject to the test, where “1” means “yes.”

Table 41. Test Asset Type Test Event Relationships

{ ta_data(t	a	test_subject	a_type_req } { test requirements for a specific asset type }	
t01	AAV	1		1
t02	AAV	1	1 { example of an excluded asset type from a test }	
t03	AAV	1		1
t04	AAV	1		1
t05	AAV	1		1
t06	AAV	1		1
t07	AAV	1		1
t08	AAV	1		1
t09	AAV	1		1
t10	AAV	1		1
t11	AAV	1		1
t12	AAV	1		1
t13	AAV	1		1
t14	AAV	1		1

{ ta_data(t	a	test_subject	a_type_req } { test requirements for a specific asset type }
t15	AAV	1	1
t16	AAV	1	1
t17	AAV	1	1
t18	AAV	1	1
t19	AAV	1	1
t20	AAV	1	1
t22	AAV	1	1
t23	AAV	1	1
t24	AAV	1	1
t25	AAV	1	1
t27	AAV	1	1
t28	AAV	1	1
t29	AAV	1	1
t33	AAV	1	1
t36	AAV	1	1
t37	AAV	1	1
t39	AAV	1	1
t40	AAV	1	1
t41	AAV	1	1
t53	AAV	1	1
t56	AAV	1	1
t57	AAV	1	1
t58	AAV	1	1
t59	AAV	1	1
t60	AAV	1	1
t61	AAV	1	1
t62	AAV	1	1
t63	AAV	1	1
t64	AAV	1	1

m. Model variable relationship a_data. The identification of test asset starting locations, and test period unavailability is contained in this file (a_data.csv), and is shown in Table 42. The first column identifies the test asset type. The second column identifies the starting test venue for the test asset type. The third column identifies the period where the test asset at the test venue starts. The fourth column identifies how many test assets of the test asset type will start at the test venue at the test period. The last column identifies test period unavailability.

Table 42. Test Asset Test Venue Starting Location and Test Period Unavailability

{ a	v	p	a_rec	unavail }
AAV	ATC_MD	p001	4	0
AAV	AVTB_CA	p001	3	0

n. Model variable relationship i_data. The identification of the deadline and the associated penalty for exceeding the deadline is given in this file (i_data.csv), and is shown in Table 43. The first column is the test event priority. The second column is the deadline test period that the test event needs to be completed by. The last column is the penalty used by the model if the model goes beyond the deadline. Low priority is identified as not having a deadline (infinity periods), and not having a penalty (0). This addresses the requirement that for low priority test asset test events can go beyond the test period. This is accomplished by a variable that can be modified to have a hard constraint, which provides greater flexibility in the model.

Table 43. Test Event Priority Deadlines and Priority Deadline Penalties

{ i	deadline	penalty }
high	170	200
medium	190	100
low	inf	0

B. OUTPUT

Output consists of restatement of some of the input data, and provides the data supporting five different test schedules (beta_min, beta_mode, mean, beta-Beta_max and t_periods). The size of this file is too large to include in this thesis, but is available upon request. The output file used in this thesis is based on a Shane Edwards model output file (email message to author, June 12, 2015).

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APPENDIX B. MODEL OUTPUT SCHEDULE CONVERSIONS AND REQUIREMENTS ASSESSMENTS

What follows in this appendix are the five manually generated schedules from the model output based on the single model run. These schedules have been manually converted from the model output to look similar to the TE schedules, using the daily time periods provided by the model. These schedules are used to develop aggregated monthly schedules in the main body of this thesis so that they can be compared against the TE schedules. The Beta_max schedule is given in Figures 21- 28. The t_periods schedule is given in Figures 29-32. The beta_min schedule is given in Figures 33-36. The beta_mode is given in Figures 37-42. The beta_mean is given in Figures 43-48.

In these tables, test assets are given as test asset TA1 through TA7 on the y-axis. Test periods P001 through Pxyz are given on the x-axis in test periods of 20 on each page (e.g. P001 - P020, P021 - P040, etc.). The cells where they intersect in the interior of the table are colored based on test venue (AVTB = blue, ATC = green, YPG = purple, and WSMR = salmon). The cells where they intersect in the interior of the table are given a font based on priority as provided in Table 37 of Appendix B (high = bold, medium = italic, low = normal). The top line of the cells in the interior of the table are the functional test as provided in the TE schedule data. The second line of the cells in the interior of the table are the actual test that will be performed on that test asset during that time period as provided in Table 31 of Appendix B (t12 = fuel consumption, t64 = firing, t59 = RGT, t40 = physical characteristics, t28 = land mode ride quality, t53 = E3 testing_limited, t58 = RGT, t15 = plow in testing, t37 = Automotive Toxic Fumes in Water).

To understand this better, let’s look at the first line for test asset TA1. TA1 in test period P001 is performing high priority initial inspection and safety checkout testing at ATC. TA1 continues this testing for all test periods through P020.

A. BETA_MAX SCHEDULE

Test Asset	Time Period																			
	P001	P002	P003	P004	P005	P006	P007	P008	P009	P010	P011	P012	P013	P014	P015	P016	P017	P018	P019	P020
TA1	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25
TA2	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25
TA3	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25
TA4	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25
TA5	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13
TA6	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13
TA7	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13

Figure 21. First Month of Model Beta_max Detailed Schedule

Time Period																				
Test Asset	P021	P022	P023	P024	P025	P026	P027	P028	P029	P030	P031	P032	P033	P034	P035	P036	P037	P038	P039	P040
TA1	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	LM t12	LM t12	LM t12	LM t12	LM t12	LM t12	LM t12	LM t12	LM t12	LM t12
TA2	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t27	S/HF t27	S/HF t27	LM t04	LM t04	LM t04	LM t04	LM t04	LM t04	LM t04
TA3	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*
TA4	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25	S/HF t25		*LM t11*	*LM t11*	*LM t11*	*LM t11*	*LM t11*	*LM t11*	*LM t11*	S/HF t28	S/HF t28
TA5	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	AVTB to WSMR	AVTB to WSMR	AVTB to WSMR	AVTB to WSMR	AVTB to WSMR	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*
TA6	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58
TA7	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13	S/HF t13							WM t15	WM t15	WM t15	WM t15

Figure 22. Second Month of Model Beta_max Detailed Schedule

	Time Period																			
Test Asset	P041	P042	P043	P044	P045	P046	P047	P048	P049	P050	P051	P052	P053	P054	P055	P056	P057	P058	P059	P060
TA1	LM t12	LM t12	LM t12	F t64	F t64	F t64	F t64	F t64	F t64	F t64	F t64	F t64	F t64	F t64	F t64	F t64	F t64	F t64	F t64	F t64
TA2	LM t59	RGT1 t59	RGT1 t59	RGT1 t59	RGT1 t59	RGT1 t59	RGT1 t59	RGT1 t59	RGT1 t59	RGT1 t59	RGT1 t59	RGT1 t59	RGT1 t59	RGT1 t59	RGT1 t59	RGT1 t59	RGT1 t59	RGT1 t59	RGT1 t59	RGT1 t59
TA3	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57
TA4	S/HF t28	S/HF t28	S/HF t28	S/HF t28	S/HF t28	S/HF t28	S/HF t28	S/HF t28	S/HF t28	S/HF t28	S/HF t28	S/HF t28	S/HF t28	S/HF t28	S/HF t28	S/HF t29	S/HF t29	S/HF t29	S/HF t29	S/HF t29
TA5	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*
TA6	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58		WM t16	WM t16	WM t16	WM t16	WM t16	WM t16	WM t16
TA7	WM t15	WM t15	WM t15	S/HF t37	S/HF t37	S/HF t37	S/HF t37	S/HF t37	S/HF t37	S/HF t37	S/HF t37	S/HF t37	S/HF t37	S/HF t37	S/HF t37	S/HF t37	S/HF t37	S/HF t37	S/HF t37	S/HF t37

Figure 23. Third Month of Model Beta_max Detailed Schedule

	Time Period																			
Test Asset	P061	P062	P063	P064	P065	P066	P067	P068	P069	P070	P071	P072	P073	P074	P075	P076	P077	P078	P079	P080
TA1	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**		**LM t10**	**LM t10**
TA2	**RGT1 t59**	**RGT1 t59**	**LM t01**	**LM t01**	**LM t01**	**S/HF t36**	**S/HF t36**	**S/HF t36**	**S/HF t36**	**S/HF t36**	**S/HF t36**	**S/HF t36**	**S/HF t36**	**S/HF t36**	**S/HF t36**	**S/HF t36**	**S/HF t36**	**S/HF t36**	**S/HF t36**	**S/HF t36**
TA3	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**LM t08**	**LM t08**	**LM t08**	**LM t08**	**LM t08**	**LM t08**	**LM t08**	**LM t08**	**LM t08**	**LM t08**	
TA4	**S/HF t29**	**S/HF t29**	**S/HF t29**	**S/HF t29**	**S/HF t29**	**S/HF t29**	**S/HF t29**	**S/HF t29**	**S/HF t29**	**S/HF t29**	**S/HF t29**	**S/HF t29**		**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**
TA5	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*
TA6		**WM t14**	**WM t14**	**WM t14**	**WM t14**	**WM t14**	**WM t14**	**WM t14**	**WM t14**	**WM t14**	**WM t14**	**WM t14**	**WM t14**	**WM t14**	**WM t14**	**WM t14**	**WM t14**	**WM t14**		**WM t19**
TA7			**WM t18**	**WM t18**	**WM t18**	**WM t18**	**WM t18**	**WM t18**	**WM t18**				**S/HF t33**	**S/HF t33**	**S/HF t33**	**S/HF t33**	**S/HF t33**	**S/HF t33**	**S/HF t33**	

Figure 24. Fourth Month of Model Beta_max Detailed Schedule

	Time Period																			
Test Asset	P081	P082	P083	P084	P085	P086	P087	P088	P089	P090	P091	P092	P093	P094	P095	P096	P097	P098	P099	P100
TA1	**LM t10**	**LM t10**	**LM t10**	**LM t10**	**LM t10**				**LM t02**	**LM t02**	**LM t02**	**LM t02**	**LM t02**	**LM t02**	**LM t02**					
TA2	**S/HF t36**	**S/HF t36**	**LM t03**	**LM t03**	**LM t03**	**LM t03**	**LM t03**	**LM t03**	**LM t03**	**LM t03**	**LM t03**	**LM t03**	**LM t03**	**LM t03**	**LM t03**					
TA3	**LM t06**	**LM t06**	**LM t06**	**LM t06**	**LM t06**	**LM t06**	**LM t06**		**LM t05**	**LM t05**	**LM t05**	**LM t05**	**LM t05**	**LM t05**	**LM t05**					
TA4	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*
TA5	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	WSMR to ATC	WSMR to ATC	WSMR to ATC	WSMR to ATC	WSMR to ATC	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*
TA6	**WM t19**	**WM t19**	**WM t17**	**WM t17**	**WM t17**	**WM t17**	**WM t17**	**WM t17**	**WM t17**	AVTB to YPG	AVTB to YPG	AVTB to YPG	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*
TA7	**WM t19**	**WM t19**	**WM t20**	**WM t20**	**WM t20**				**WM t22**	**WM t22**	**WM t22**	**WM t22**	**WM t22**	**WM t22**	**WM t22**	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*

Figure 25. Fifth Month of Model Beta_max Detailed Schedule

Time Period																				
Test Asset	P101	P102	P103	P104	P105	P106	P107	P108	P109	P110	P111	P112	P113	P114	P115	P116	P117	P118	P119	P120
TA1																				
TA2										*LM t07*	*LM t07*	*LM t07*	*LM t07*	*LM t07*	*LM t07*	*LM t07*				
TA3										*LM t07*	*LM t07*	*LM t07*	*LM t07*	*LM t07*	*LM t07*	*LM t07*				
TA4	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*			
TA5	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*
TA6	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*
TA7	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*

Figure 26. Sixth Month of Model Beta_max Detailed Schedule

Time Period																				
Test Asset	P121	P122	P123	P124	P125	P126	P127	P128	P129	P130	P131	P132	P133	P134	P135	P136	P137	P138	P139	P140
TA1					ATC to AVTB	ATC to AVTB	ATC to AVTB	ATC to AVTB	ATC to AVTB	ATC to AVTB	*WM t24*	*WM t24*	*WM t24*	*WM t24*	*WM t24*	*WM t24*	*WM t24*	*WM t24*	*WM t24*	*WM t24*
TA2																	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*
TA3													*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*
TA4						*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*
TA5	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*
TA6	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*
TA7	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*

Figure 27. Seventh Month of Model Beta_max Detailed Schedule

	Time Period																			
Test Asset	P141	P142	P143	P144	P145	P146	P147	P148	P149	P150	P151	P152	P153	P154	P155	P156	P157	P158	P159	P160
TA1								*WM t23*	*WM t23*	*WM t23*	*WM t23*	*WM t23*	*WM t23*	*WM t23*	*WM t23*	*WM t23*	*WM t23*			
TA2	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*		
TA3	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*						
TA4	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*		
TA5	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*			
TA6	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	
TA7	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*			*WM t23*	*WM t23*	*WM t23*	*WM t23*	*WM t23*	*WM t23*	*WM t23*	*WM t23*	*WM t23*	*WM t23*			

Figure 28. Eighth Month of Model Beta_max Detailed Schedule

Table 44 is used to compare the input file to the schedule developed from the model output. The “Test Event” column is the test event from which all comparisons are made. “Test Asset Input” is the number of test assets that are used to perform the test event based on the input file. “Actual Test Assets” is the number of test assets used based on the output provided and what is shown in the schedule. “Test Period Input” is the number of test periods that are used based on the input file. “Actual Test Periods” is the number of test periods that the output provided and what is shown in the schedule. “Input Location” is the location where the test event can be performed based on the input file. “Actual Location” is where the test event is performed based on the output provided and what is shown in the schedule. The “Successor” column provides test events that are successors to the test event on the left of the table. The “Successor Success?” column is the assessment of whether that test event is started after the test event on the left is completed or not with an answer of “yes” or “no.” The last column, “Priority” is the priority from the input file.

Table 44. Model Input Files to Model Beta_max Detailed Schedule Comparison

Test Event	Test Asset Input	Actual Test Assets	Test Period Input	Actual Test Periods	Input Location	Actual Location	Successor	Successor Success?	Priority
t01	1	1	3	3	ATC_MD	ATC	t02	yes	high
t02	1	1	7	7	ATC_MD	ATC			high
t03	1	1	13	13	ATC_MD	ATC			high
t04	1	1	7	7	ATC_MD	ATC			high
t05	1	1	7	7	ATC_MD	ATC			high
t06	1	1	7	7	ATC_MD	ATC			high
t07	2	2	7	7	ATC_MD	ATC			medium
t08	1	1	10	10	ATC_MD	ATC			high
t09	1	1	33	33	ATC_MD	ATC			medium
t10	1	1	7	7	ATC_MD	ATC			high
t11	1	1	7	7	ATC_MD	ATC	t09	yes	medium
t12	1	1	13	13	ATC_MD	ATC			high
t13	3	3	30	30	AVTB_CA	AVTB	t14, t15, t16, t17, t18, t19, t20, t22, t23, t24, t63	yes	high
t14	1	1	17	17	AVTB_CA	AVTB			high
t15	1	1	7	7	AVTB_CA	AVTB	t16, t17, t18	yes	high
t16	1	1	7	7	AVTB_CA	AVTB			high
t17	1	1	7	7	AVTB_CA	AVTB			high
t18	1	1	7	7	AVTB_CA	AVTB			high
t19	2	1	3	3	AVTB_CA	AVTB			high
t20	1	1	3	3	AVTB_CA	AVTB			high
t22	1	1	7	7	AVTB_CA	AVTB			high
t23	2	2	10	10	AVTB_CA	AVTB			medium
t24	1	1	10	10	AVTB_CA	AVTB			medium
t25	4	4	30	30	ATC_MD	ATC	t01, t02, t03, t04, t05, t06, t07, t08,t09, t10, t11, t12, t14, t15, t16, t17, t18, t19, t20, t22, t23, t24, t27, t28, t29, t33, t36, t39, t40, t41,	yes	high

Test Event	Test Asset Input	Actual Test Assets	Test Period Input	Actual Test Periods	Input Location	Actual Location	Successor	Successor Success?	Priority
							t53, t64		
t27	1	1	3	3	ATC_MD	ATC			high
t28	1	1	17	17	ATC_MD	ATC			high
t29	1	1	17	17	ATC_MD	ATC			high
t33	1	1	7	7	AVTB_CA	AVTB			high
t36	1	1	17	17	ATC_MD	ATC			high
t37	1	1	17	17	AVTB_CA	AVTB			high
t39	1	1	67	67	ATC_MD	ATC			medium
t40	1	1	17	17	ATC_MD	ATC	t39	yes	medium
t41	1	1	67	67	ATC_MD YPG_AZ	WSMR			medium
t53	1	1	50	50	WSMR_NM	WSMR	t22	yes	medium
t56	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	ATC			high
t57	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	ATC			high
t58	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	AVTB			high
t59	1	22	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	ATC			high
t60	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	ATC			medium

Test Event	Test Asset Input	Actual Test Assets	Test Period Input	Actual Test Periods	Input Location	Actual Location	Successor	Successor Success?	Priority
t61	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	ATC			medium
t62	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	ATC			medium
t63	1	1	50	50	AVTB_CA	AVTB			medium
t64	1		34	34	ATC_MD	ATC			high

Using the information provided in the Beta_max schedule and the comparison table, the verification assessment results for Beta_max schedule generated by the model is given in the Table 45 in the "Verification & Rationale" column, which is relative to Table 4 requirements that are repeated here.

Table 45. Model Controls and Constraints Beta_max Schedule Verification

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.0	Controls and Constraints	Not Applicable	Not Applicable	Not Applicable
2.1	Test Period (T=O)	The TE RSCSP model schedule shall be constrained by the test period.	The requirement shall be verified by confirming that the schedule is within the test period given in the test period input file.	MET Test period is 180 and model test period is 159 days.
2.1.1	One Test Event on Test Asset during Time Period (T=O)	The TE RSCSP model shall not allow more than one test event during a time period on a test asset.	The requirement shall be verified by confirming that the schedule does not show more than one test event in a time period on a test asset.	PARTIALLY MET Output file does not assign a test asset, but in aggregate does not exceed the number of test assets.
2.1.2	Place all Test Events in Test Period (T=O)	The TE RSCSP model shall place all identified test events in a test period.	The requirement shall be verified by confirming that schedule places all identified test events in a test period.	MET Actual test events from input file are all placed in test periods.
2.1.3	Test Event Test Period Durations (T=O)	The TE RSCSP model shall use the test event test period durations input.	The requirement shall be verified by confirming that schedule test event test period durations matches the test events test period input file.	MET Actual test event test periods tracks to input tile.

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.2	Test Events (T=O)	The TE RSCSP model schedule shall be constrained by the test events.	The requirement shall be verified by confirming that the schedule includes all test events included in the test events input file.	MET
2.3	Test Asset Type (O)	The TE RSCSP model shall use test asset type inputs.	The requirement shall be verified by confirming that schedule results places test events on the applicable test asset type based on the input file.	NOT VERIFIED Input files did not use more than one test asset type.
2.4	Test Venues (T=O)	The TE RSCSP model shall use test venues input.	The requirement shall be verified by confirming that the schedule includes only the test venues included in the test venues input file.	MET Actual test venues used track to input file.
2.5	Test Event Priorities	Not Applicable	Not Applicable	Not Applicable
2.5.1	Test Event Priority Relationships (T=O)	The TE RSCSP model shall be constrained by the test event priority relationships	The requirement shall be verified by confirming that schedule results are constrained by the test event priority relationships input file.	PARTIALLY MET In most cases, MET. There is an issue with t33 and t37 medium happening before high priority tests.
2.5.2	High to Medium Priority Relationship (T=O)	The TE RSCSP model high priority test events shall be started before medium priority test events.	The requirement shall be verified by confirming that schedule starts high priority test events before medium priority test events.	PARTIALLY MET
2.5.3	Medium to Low Priority Relationship (T=O)	The TE RSCSP model medium priority test events shall be started before low priority test events.	The requirement shall be verified by confirming that schedule starts medium priority test events before low priority test events.	NOT VERIFIED Model run did not include any low priority test events.

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.5.4	High to Low Priority Relationships (T=O)	The TE RSCSP model high priority test events shall be started before low priority test events.	The requirement shall be verified by confirming that schedule starts high priority test events before low priority test events.	NOT VERIFIED Model run did not include any low priority test events.
2.6	Test Venue Movement Test Periods (T=O)	The TE RSCSP model shall be constrained by the test venue movement test periods.	The requirement shall be verified by confirming that schedule uses the test venue movement test periods based on the input file.	MET Data shows that when moving venues, the input data matches the input file.
2.6.1	Add Time Period from Test Venue Movement (T=O)	The TE RSCSP model shall add time periods to the schedule based on the distance between test venues.	The requirement shall be verified by confirming that schedule results show that the time periods added to the schedule when the test asset moves to a new test venue are based on the input file.	MET
2.6.2	Schedule Test Event on Available Test Venues (T=O)	The TE RSCSP model shall not schedule a test event at a test venue that does not perform that test event.	The requirement shall be verified by confirming that schedule results show that the test events are scheduled only on available test venues based on the input file.	MET Test venues used track to test venues allowed based on the input file.
2.7	Test Venue Test Asset Capacity (T=O)	The TE RSCSP model shall be constrained by test venue test asset capacity input.	The requirement shall be verified by confirming that the number of test assets located at each test venue on the schedule does not exceed the capacity identified in the input file.	NOT VERIFIED The number of test assets assigned to a test venue by the model did not exceed the amount in the file, but the numbers in the file (10) did not really check the model.

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.8	Test Asset Test Venue Starting Location (T=O)	The TE RSCSP model shall be constrained by the test asset test venue starting location input.	The requirement shall be verified by confirming that schedule test assets start at the venues identified in the test asset test venue input file.	MET
2.9	Test Event Test Venue Relationships (T=O)	The TE RSCSP model shall be constrained by the test event test venue relationships input.	The requirement shall be verified by confirming that schedule test events are performed at the test venues identified in the test event test venue relationships input file.	MET
2.10	Test Event Precedence Relationships (T=O)	The TE RSCSP model shall be constrained by test event precedence relationships input.	The requirement shall be verified by confirming that schedule results are constrained by the test event precedence relationships input file.	MET Data shows that predecessor test events in the schedule occur before successor test events.
2.10.1	Test Event Predecessor First (T=O)	The TE RSCSP model shall perform predecessor test events prior to test event successor test events.	The requirement shall be verified by confirming that predecessor test events are on the schedule before successor test events regardless of test event priority.	MET Data shows that predecessor test events in the schedule occur before successor test events.
2.10.2	Test Event Successor Second (T=O)	The TE RSCSP model shall not perform successor test events prior to test event predecessor test events.	The requirement shall be verified by confirming that successor test events are on the schedule before predecessor test events regardless of test event priority.	MET

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.11	Number of Test Assets Needed for Test Events (T=O)	The TE RSCSP model shall use the number of test assets needed for test events input.	The requirement shall be verified by confirming that the schedule uses the number of test assets needed for test events input file.	MET
2.12	Low Priority Schedule Relationship (O)	The TE RSCSP model low priority test events shall be allowed to go beyond the test period.	The requirement shall be verified by confirming that schedule results match the input file.	NOT VERIFIED Low priority test events are not used in this model run.
2.13	Test Asset Unavailability (O)	The TE RSCSP model shall be constrained by the test asset unavailability.	The requirement shall be verified by confirming that schedule places test assets only on available test assets based on the input file.	NOT VERIFIED Data for Test Asset Unavailability is not included in the model run.
2.14	Test Venue Unavailability (O)	The TE RSCSP model shall be constrained by test venue unavailability.	The requirement shall be verified by confirming that schedule results are constrained by the input file.	NOT VERIFIED Data for Test Venue Unavailability is not included in the model run.
2.15	Test Event Priority Deadlines (T=O)	The TE RSCSP model shall be constrained by the high and medium test event priority deadlines.	The requirement shall be verified by confirming that schedule results are constrained by the input file.	PARTIALLY MET
2.15.1	High Priority to Deadline Relationship (T=O)	The TE RSCSP model shall complete high priority test events before high priority deadlines.	The requirement shall be verified by confirming that schedule results start high priority test events before the high priority deadline.	MET
2.15.2	Medium Priority to Deadline Relationship (T=O)	The TE RSCSP model shall complete medium priority test events before medium priority deadlines.	The requirement shall be verified by confirming that schedule results start medium priority test events before the medium priority deadline.	NOT VERIFIED This model run used 190 for the total test periods and the medium test periods, which means that it is not verified.

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.15.3	High Priority to Test Period Relationship (T=O)	The TE RSCSP model shall complete high priority test events before the test period completes.	The requirement shall be verified by confirming that schedule results complete high priority test events before the test period completes.	MET High priority test events end at 95. Schedule ends at test period 159. Test period ends at 190.
2.15.4	Medium Priority to Test Period Relationship (T=O)	The TE RSCSP model shall complete medium priority test events before the test period completes.	The requirement shall be verified by confirming that schedule results complete medium priority test events before the test period completes.	MET Medium priority test events end at test period 159. Schedule ends at test period 159. Test period ends at 190.

The results of the model controls and constraints requirements verification assessment for Beta_max indicate that the majority of the threshold model controls and constraints requirements in Table 4 are MET, except for some that are PARTIALLY MET and some that are NOT VERIFIED. There are no controls and constraints requirements that are verified to be NOT MET.

Partially Met requirements. Data used for verification for time period, priority deadlines did not fully test the time period due to the values used. The following are considered to be PARTIALLY MET, and require an additional verification event in order to be fully assessed: One Test Event on Test Asset during Time Period, Test Event Priority Relationships, High to Medium Priority Relationship, and Test Event Priority Deadlines.

Not Verified requirements. Data did not include low priority test events, test asset type, test venue capacity, test asset unavailability, test venue unavailability, and medium deadline. The following are considered to be NOT VERIFIED, and require an additional verification event in order to be assessed: Medium to Low Priority Relationship, High to Low Priority Relationships, Test Venue Test Asset Capacity, Test Asset Type Test Event Relationships, Test

Asset Unavailability, Test Venue Unavailability, Medium Priority to Deadline Relationship, and Low Priority Schedule Relationship.

B. T_PERIODS SCHEDULE

	Time Period																			
Test Asset	P001	P002	P003	P004	P005	P006	P007	P008	P009	P010	P011	P012	P013	P014	P015	P016	P017	P018	P019	P020
TA1	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	ATC to WSMR	ATC to WSMR	ATC to WSMR	ATC to WSMR	ATC to WSMR	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*
TA2	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**LM t06**	**LM t06**	**LM t01**	**LM t12**	**LM t12**	**LM t12**	**LM t12**	**LM t02**	**LM t02**	*LM t11*	*LM t11*
TA3	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t27**	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	**LM t04**	**LM t04**		**RGT1 t57**	**RGT1 t57**
TA4	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**
TA5		**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**						**WM t19**	**WM t14**	**WM t14**	**WM t14**	**WM t14**
TA6		**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**						**WM t19**	**S/HF t37**	**S/HF t37**	**S/HF t37**	**S/HF t37**
TA7		**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**						**WM t20**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**

Figure 29. First Month of Model t_periods Detailed Schedule

Test Asset	Time Period																			
	P021	P022	P023	P024	P025	P026	P027	P028	P029	P030	P031	P032	P033	P034	P035	P036	P037	P038	P039	P040
TA1	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	LM t60	LM t60	LM t60	LM t60	LM t60	LM t60	LM t60	LM t60	LM t60	LM t60	LM t60
TA2				**LM t08**	**LM t08**	**LM t08**	**LM t10**	**LM t10**	**S/HF t28**	**S/HF t28**	**S/HF t28**	**S/HF t28**	**S/HF t28**	*LM t07*	*LM t07*		*LM t09*	*LM t09*	*LM t09*	*LM t09*
TA3	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**
TA4	**F t64**	**F t64**	**F t64**	**F t64**	**S/HF t36**	**S/HF t36**	**S/HF t36**	**S/HF t36**	**S/HF t36**	**LM t05**	**LM t05**			*LM t07*	*LM t07*					
TA5	**WM t14**	*WM t24*	*WM t24*	*WM t24*	**WM t15**	**WM t15**	**WM t18**	**WM t18**	**WM t17**	**WM t17**	**WM t16**	**WM t16**							**WM t22**	**WM t22**
TA6	**S/HF t37**	**WM t33**	**WM t33**	**RGT1 t58**	**RGT1 t58**	**RGT1 t58**	**RGT1 t58**	**RGT1 t58**	**RGT1 t58**	**RGT1 t58**	**RGT1 t58**	**RGT1 t58**	**RGT1 t58**	**RGT1 t58**	**RGT1 t58**	**RGT1 t58**	**RGT1 t58**	**RGT1 t58**	**RGT1 t58**	**RGT1 t58**
TA7	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	*RGT2 t61*	*RGT2 t61*

Figure 30. Second Month of Model t_periods Detailed Schedule

	Time Period																			
Test Asset	P041	P042	P043	P044	P045	P046	P047	P048	P049	P050	P051	P052	P053	P054	P055	P056	P057	P058	P059	P060
TA1	LM t60	LM t60	LM t60	LM t60	LM t60	LM t60	LM t60	LM t60	LM t60	LM t60	LM t60									
TA2	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*
TA3	**LM t03**	**LM t03**	**LM t03**	**LM t03**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**
TA4	**S/HF t29**	**S/HF t29**	**S/HF t29**	**S/HF t29**	**S/HF t29**	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*
TA5	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*
TA6	**RGT1 t58**	**RGT1 t58**	**RGT1 t58**	**RGT1 t58**	**RGT1 t58**	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*
TA7	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*

Figure 31. Third Month of Model t_periods Detailed Schedule

	Time Period																			
Test Asset	P061	P062	P063	P064	P065	P066	P067	P068	P069	P070	P071	P072	P073	P074	P075	P076	P077	P078	P079	P080
TA1																				
TA2	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*														
TA3	**RGT 1 t59**	**RGT 1 t59**	**RGT 1 t59**	**RGT 1 t59**	**RGT 1 t59**	**RGT 1 t59**														
TA4	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*															
TA5	*RGT 2 t62*	*RGT 2 t62*	*WM t23*	*WM t23*	*WM t23*															
TA6	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*														
TA7			*WM t23*	*WM t23*	*WM t23*															

Figure 32. Fourth Month of Model t_periods Detailed Schedule

Table 46. Model Input Files to Model t_periods Detailed Schedule Comparison

Test Event	Test Asset Input	Actual Test Assets	Test Period Input	Actual Test Periods	Input Location	Actual Location	Successor	Successor Success?	Priority	Priority Notes
t01	1	1	1	1	ATC_MD	ATC	t02	Yes	high	
t02	1	1	2	2	ATC_MD	ATC			high	
t03	1	1	4	4	ATC_MD	ATC			high	
t04	1	1	2	2	ATC_MD	ATC			high	
t05	1	1	2	2	ATC_MD	ATC			high	
t06	1	1	2	2	ATC_MD	ATC			high	
t07	2	2	2	2	ATC_MD	ATC			medium	performed before high tasks
t08	1	1	3	3	ATC_MD	ATC			high	
t09	1	1	10	10	ATC_MD	ATC			medium	performed before high tasks
t10	1	1	2	2	ATC_MD	ATC			high	
t11	1	1	2	2	ATC_MD	ATC	t09	Yes	medium	performed before high tasks
t12	1	1	4	4	ATC_MD	ATC			high	
t13	3	3	9	9	AVTB_CA	AVTB	t14, t15, t16, t17, t18, t19, t20, t22, t23, t24, t63	Yes	high	
t14	1	1	5	5	AVTB_CA	AVTB			high	

Test Event	Test Asset Input	Actual Test Assets	Test Period Input	Actual Test Periods	Input Location	Actual Location	Successor	Successor Success?	Priority	Priority Notes
t15	1	1	2	2	AVTB_CA	AVTB	t16, t17, t18	Yes	high	
t16	1	1	2	2	AVTB_CA	AVTB			high	
t17	1	1	2	2	AVTB_CA	AVTB			high	
t18	1	1	2	2	AVTB_CA	AVTB			high	
t19	2	2	1	1	AVTB_CA	AVTB			high	
t20	1	1	1	1	AVTB_CA	AVTB			high	
t22	1	1	2	2	AVTB_CA	AVTB			high	performed before high tasks
t23	2	2	3	3	AVTB_CA	AVTB			medium	
t24	1	1	3	3	AVTB_CA	AVTB			medium	performed before high tasks
t25	4	4	9	9	ATC_MD	ATC	t01, t02, t03, t04, t05, t06, t07, t08, t09, t10, t11, t12, t14, t15, t16, t17, t18, t19, t20, t22, t23, t24, t27, t28, t29, t33, t36, t39 t40, t41, t53, t64	Yes. Note that this should only be for ATC, not AVTB tests	high	
t27	1	1	1	1	ATC_MD	ATC			high	
t28	1	1	5	5	ATC_MD	ATC			high	
t29	1	1	5	5	ATC_MD	ATC			high	
t33	1	1	2	2	AVTB_CA	AVTB			high	

Test Event	Test Asset Input	Actual Test Assets	Test Period Input	Actual Test Periods	Input Location	Actual Location	Successor	Successor Success?	Priority	Priority Notes
t36	1	1	5	5	ATC_MD	ATC			high	
t37	1	1	5	5	AVTB_CA	AVTB			high	
t39	1	1	20	20	ATC_MD	ATC			medium	
t40	1	1	5	5	ATC_MD	ATC	t39	Yes	medium	performed before high tasks
t41	1	1	20	20	ATC_MD YPG_AZ	ATC			medium	
t53	1	1	15	15	WSMR_NM	WSMR	t22	Yes	medium	
t56	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	AVTB			high	
t57	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	ATC			high	
t58	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	AVTB			high	
t59	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	ATC			high	should have been performed on a different vehicle and earlier

Test Event	Test Asset Input	Actual Test Assets	Test Period Input	Actual Test Periods	Input Location	Actual Location	Successor	Successor Success?	Priority	Priority Notes
t60	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	WSMR			medium	performed before high tasks
t61	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	AVTB			medium	
t62	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	AVTB			medium	
t63	1	1	21	21	AVTB_CA	AVTB			medium	
t64	1	1	15	15	ATC_MD	ATC			high	

Using the information provided in the t_periods schedule and the comparison table, the verification assessment results for t_periods schedule generated by the model is given in the Table 47 in the "Verification & Rationale" column, which is relative to Table 4 requirements that are repeated here.

Table 47. Model Controls and Constraints t_periods Schedule Verification

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.0	Controls and Constraints	Not Applicable	Not Applicable	Not Applicable
2.1	Test Period (T=O)	The TE RSCSP model schedule shall be constrained by the test period.	The requirement shall be verified by confirming that the schedule is within the test period given in the test period input file.	MET Test period is 180 and model test period used is 66 days.
2.1.1	One Test Event on Test Asset during Time Period (T=O)	The TE RSCSP model shall not allow more than one test event during a time period on a test asset.	The requirement shall be verified by confirming that the schedule does not show more than one test event in a time period on a test asset.	PARTIALLY MET Output File does not assign a test asset, but in aggregate does not exceed the number of test assets.
2.1.2	Place all Test Events in Test Period (T=O)	The TE RSCSP model shall place all identified test events in a test period.	The requirement shall be verified by confirming that schedule places all identified test events in a test period.	MET Actual test events from input file are all placed in test periods.
2.1.3	Test Event Test Period Durations (T=O)	The TE RSCSP model shall use the test event test period durations input.	The requirement shall be verified by confirming that schedule test event test period durations matches the test events test period input file.	MET Actual test event test periods tracks to input tile.
2.2	Test Events (T=O)	The TE RSCSP model schedule shall be constrained by the test events.	The requirement shall be verified by confirming that the schedule includes all test events included in the test events input file.	MET Actual test events used track to input file.
2.3	Test Asset Type (O)	The TE RSCSP model shall use test asset type inputs.	The requirement shall be verified by confirming that schedule results places test events on the applicable test asset type based on the input file.	NOT VERIFIED Input files did not use more than one test asset type.

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.4	Test Venues (T=O)	The TE RSCSP model shall use test venues input.	The requirement shall be verified by confirming that the schedule includes only the test venues included in the test venues input file.	MET Actual test venues used track to input file.
2.5	Test Event Priorities	Not Applicable	Not Applicable	Not Applicable
2.5.1	Test Event Priority Relationships (T=O)	The TE RSCSP model shall be constrained by the test event priority relationships	The requirement shall be verified by confirming that schedule results are constrained by the test event priority relationships input file.	PARTIALLY MET In most cases, MET. There is an issue with t07, t11, t22, t24, t40, and t59 medium test events happening before high priority tests.
2.5.2	High to Medium Priority Relationship (T=O)	The TE RSCSP model high priority test events shall be started before medium priority test events.	The requirement shall be verified by confirming that schedule starts high priority test events before medium priority test events.	PARTIALLY MET In most cases, MET. There is an issue with t07, t11, t22, t24, t40, and t59 medium happening before high priority tests.
2.5.3	Medium to Low Priority Relationship (T=O)	The TE RSCSP model medium priority test events shall be started before low priority test events.	The requirement shall be verified by confirming that schedule starts medium priority test events before low priority test events.	NOT VERIFIED Model run did not include any low priority test events.
2.5.4	High to Low Priority Relationships (T=O)	The TE RSCSP model high priority test events shall be started before low priority test events.	The requirement shall be verified by confirming that schedule starts high priority test events before low priority test events.	NOT VERIFIED Model run did not include any low priority test events.
2.6	Test Venue Movement Test Periods (T=O)	The TE RSCSP model shall be constrained by the test venue movement test periods.	The requirement shall be verified by confirming that schedule uses the test venue movement test periods based on the input file.	MET Data shows that when moving venues, the input data matches the input file.
2.6.1	Add Time Period from Test Venue Movement (T=O)	The TE RSCSP model shall add time periods to the schedule based on the distance between test venues.	The requirement shall be verified by confirming that schedule results show that the time periods added to the schedule when the test asset moves to a new test venue are based on the input file.	MET Data shows that when moving venues, the input file test periods are added to the test schedule.

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.6.2	Schedule Test Event on Available Test Venues (T=O)	The TE RSCSP model shall not schedule a test event at a test venue that does not perform that test event.	The requirement shall be verified by confirming that schedule results show that the test events are scheduled only on available test venues based on the input file.	MET Test venues used track to test venues allowed based on the input file.
2.7	Test Venue Test Asset Capacity (T=O)	The TE RSCSP model shall be constrained by test venue test asset capacity input.	The requirement shall be verified by confirming that the number of test assets located at each test venue on the schedule does not exceed the capacity identified in the input file.	NOT VERIFIED The number of test assets assigned to a test venue by the model did not exceed the amount in the file, but the numbers in the file (10) did not really check the model.
2.8	Test Asset Test Venue Starting Location (T=O)	The TE RSCSP model shall be constrained by the test asset test venue starting location input.	The requirement shall be verified by confirming that schedule test assets start at the venues identified in the test asset test venue input file.	MET The starting locations and quantities (4 at ATC and 3 at AVTB) track to the input file.
2.9	Test Event Test Venue Relationships (T=O)	The TE RSCSP model shall be constrained by the test event test venue relationships input.	The requirement shall be verified by confirming that schedule test events are performed at the test venues identified in the test event test venue relationships input file.	MET Test events are assigned to allowed test venues based on the input file.
2.10	Test Event Precedence Relationships (T=O)	The TE RSCSP model shall be constrained by test event precedence relationships input.	The requirement shall be verified by confirming that schedule results are constrained by the test event precedence relationships input file.	MET Data shows that predecessor test events in the schedule occur before successor test events.
2.10.1	Test Event Predecessor First (T=O)	The TE RSCSP model shall perform predecessor test events prior to test event successor test events.	The requirement shall be verified by confirming that predecessor test events are on the schedule before successor test events regardless of test event priority.	MET Data shows that predecessor test events in the schedule occur before successor test events.

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.10.2	Test Event Successor Second (T=O)	The TE RSCSP model shall not perform successor test events prior to test event predecessor test events.	The requirement shall be verified by confirming that successor test events are on the schedule before predecessor test events regardless of test event priority.	MET Data shows that successor test events in the schedule occur after predecessor test events.
2.11	Number of Test Assets Needed for Test Events (T=O)	The TE RSCSP model shall use the number of test assets needed for test events input.	The requirement shall be verified by confirming that the schedule uses the number of test assets needed for test events input file.	MET Data shows that the number of test assets needed for a test event are used. For multi-vehicle operations, tests are performed simultaneously on the test assets.
2.12	Low Priority Schedule Relationship (O)	The TE RSCSP model low priority test events shall be allowed to go beyond the test period.	The requirement shall be verified by confirming that schedule results match the input file.	NOT VERIFIED Low priority test events are not used in this model run.
2.13	Test Asset Unavailability (O)	The TE RSCSP model shall be constrained by the test asset unavailability.	The requirement shall be verified by confirming that schedule places test assets only on available test assets based on the input file.	NOT VERIFIED Data for Test Asset Unavailability is not included in the model run.
2.14	Test Venue Unavailability (O)	The TE RSCSP model shall be constrained by test venue unavailability.	The requirement shall be verified by confirming that schedule results are constrained by the input file.	NOT VERIFIED Data for Test Venue Unavailability is not included in the model run.
2.15	Test Event Priority Deadlines (T=O)	The TE RSCSP model shall be constrained by the high and medium test event priority deadlines.	The requirement shall be verified by confirming that schedule results are constrained by the input file.	PARTIALLY MET This model run used 190 for the total test periods. High is 170, and medium is 190.

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.15.1	High Priority to Deadline Relationship (T=O)	The TE RSCSP model shall complete high priority test events before high priority deadlines.	The requirement shall be verified by confirming that schedule results start high priority test events before the high priority deadline.	MET This model run used 190 for the total test periods. High test periods is 170, and there are no high priority test events that go beyond this deadline. Schedule ends at test period 66.
2.15.2	Medium Priority to Deadline Relationship (T=O)	The TE RSCSP model shall complete medium priority test events before medium priority deadlines.	The requirement shall be verified by confirming that schedule results start medium priority test events before the medium priority deadline.	NOT VERIFIED This model run used 190 for the total test periods and the medium test periods, which means that it is not verified.
2.15.3	High Priority to Test Period Relationship (T=O)	The TE RSCSP model shall complete high priority test events before the test period completes.	The requirement shall be verified by confirming that schedule results complete high priority test events before the test period completes.	MET High priority test events end at 66. Schedule ends at test period 66. Test period ends at 190.
2.15.4	Medium Priority to Test Period Relationship (T=O)	The TE RSCSP model shall complete medium priority test events before the test period completes.	The requirement shall be verified by confirming that schedule results complete medium priority test events before the test period completes.	MET Medium priority test events end at test period 66. Schedule ends at test period 66. Test period ends at 190.

The results of the model controls and constraints requirements schedule verification assessment for t_periods indicate that the majority of the threshold model controls and constraints requirements in Table 4 are MET, except for some that are PARTIALLY MET and some that are NOT VERIFIED. There are no controls and constraints requirements that are verified to be NOT MET.

Partially Met requirements. Data used for verification for time period, priority deadlines did not fully test the time period due to the values used. The following are considered to be PARTIALLY MET, and require an additional

verification event in order to be fully assessed: One Test Event on Test Asset during Time Period, Test Event Priority Relationships, High to Medium Priority Relationship, and Test Event Priority Deadlines.

Not Verified requirements. Data did not include low priority test events, test asset type, test venue capacity, test asset unavailability, test venue unavailability, and medium deadline. The following are considered to be NOT VERIFIED, and require an additional verification event in order to be assessed: Medium to Low Priority Relationship, High to Low Priority Relationships, Test Venue Test Asset Capacity, Test Asset Type Test Event Relationships, Test Asset Unavailability, Test Venue Unavailability, Medium Priority to Deadline Relationship, and Low Priority Schedule Relationship.

C. BETA_MIN SCHEDULE

	Time Period																			
Test Asset	P001	P002	P003	P004	P005	P006	P007	P008	P009	P010	P011	P012	P013	P014	P015	P016	P017	P018	P019	P020
TA1	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**LM t01**	**S/HF t27**	*LM t11*	*LM t11*	*LM t11*	**LM t04**	**LM t04**
TA2	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t28**	**LM t28**	**LM t28**	**LM t28**	**LM t28**	**LM t28**	**LM t28**
TA3	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*
TA4	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**
TA5			**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	AVTB to WSMR	AVTB to WSMR	AVTB to WSMR	*S t53*	*S t53*
TA6			**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**					**S/HF t33**
TA7			**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**

Figure 33. First Month of Model Beta_min Detailed Schedule

Time Period																				
Test Asset	P021	P022	P023	P024	P025	P026	P027	P028	P029	P030	P031	P032	P033	P034	P035	P036	P037	P038	P039	P040
TA1	**LM t04**	**S/HF t36**	**S/HF t36**	**S/HF t36**	**S/HF t36**	**S/HF t36**	**S/HF t36**	**S/HF t36**	**LM t05**	**LM t05**	**LM t05**	**RGT 1 t59**	**RGT 1 t59**	**RGT 1 t59**	**RGT 1 t59**	**RGT 1 t59**	**RGT 1 t59**	**RGT 1 t59**	**RGT 1 t59**	**RGT 1 t59**
TA2	**LM t10**	**LM t10**	**LM t10**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**LM t12**	**LM t12**
TA3	**RGT 1 t58**	**RGT 1 t58**	**RGT 1 t58**	**RGT 1 t58**	**RGT 1 t58**	**RGT 1 t58**	**RGT 1 t58**	**RGT 1 t58**	**RGT 1 t58**	**RGT 1 t58**	**RGT 1 t58**	**RGT 1 t58**	**RGT 1 t58**	**RGT 1 t58**	**RGT 1 t58**	**RGT 1 t58**	**RGT 1 t58**	**RGT 1 t58**	**RGT 1 t58**	**RGT 1 t58**
TA4	**RGT 1 t57**	**RGT 1 t57**	**RGT 1 t57**	**RGT 1 t57**	**RGT 1 t57**	**RGT 1 t57**	**RGT 1 t57**	**RGT 1 t57**	**RGT 1 t57**	**RGT 1 t57**	**RGT 1 t57**	**RGT 1 t57**	**RGT 1 t57**	**RGT 1 t57**	**RGT 1 t57**	**LM t03**	**LM t03**	**LM t03**	**LM t03**	**LM t03**
TA5	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*RGT2 t62*
TA6	**S/HF t33**	**S/HF t33**			**WM t15**	**WM t15**	**WM t15**	**WM t20**		**WM t18**	**WM t18**	**WM t18**	**WM t16**	**WM t16**	**WM t16**	**WM t14**	**WM t14**	**WM t14**	**WM t14**	**WM t14**
TA7	**RGT 1 t56**	**RGT 1 t56**	**RGT 1 t56**	**RGT 1 t56**	**RGT 1 t56**	**RGT 1 t56**	**RGT 1 t56**	**RGT 1 t56**	**RGT 1 t56**	**RGT 1 t56**	**RGT 1 t56**	**RGT 1 t56**	**RGT 1 t56**	**RGT 1 t56**	**RGT 1 t56**	**RGT 1 t56**	**RGT 1 t56**	**WM t17**	**WM t17**	**WM t17**

Figure 34. Second Month of Model Beta_min Detailed Schedule

	Time Period																			
Test Asset	P041	P042	P043	P044	P045	P046	P047	P048	P049	P050	P051	P052	P053	P054	P055	P056	P057	P058	P059	P060
TA1	**RGT 1 t59**	**RGT 1 t59**	**RGT 1 t59**	**RGT 1 t59**	**RGT 1 t59**	**RGT 1 t59**	**RGT 1 t59**	**RGT 1 t59**	**RGT 1 t59**	**RGT 1 t59**	**RGT 1 t59**	**RGT 1 t59**	**RGT 1 t59**			*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*
TA2	**LM t12**	**LM t12**	**LM t12**	**LM t12**	**LM t08**	**LM t08**	**LM t08**	**LM t08**	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*
TA3	**RGT 1 t58**	**RGT 1 t58**	**S/HF t29**	**S/HF t29**	**S/HF t29**	**S/HF t29**	**S/HF t29**	**S/HF t29**	**S/HF t29**	**S/HF t06**	**S/HF t06**	**S/HF t06**								
TA4	**LM t03**	**LM t02**	**LM t02**	**LM t02**				*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*
TA5	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*
TA6	**WM t14**	**WM t14**	**WM t19**			**WM t22**	**WM t22**	**WM t22**	*WM t24*	*WM t24*	*WM t24*	*WM t24*				*C t63*	*C t63*	*C t63*	*C t63*	*C t63*
TA7			**WM t19**		**S/HF t37**	**S/HF t37**	**S/HF t37**	**S/HF t37**	**S/HF t37**	**S/HF t37**	**S/HF t37**	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*

Figure 35. Third Month of Model Beta_min Detailed Schedule

	Time Period																			
Test Asset	P061	P062	P063	P064	P065	P066	P067	P068	P069	P070	P071	P072	P073	P074	P075	P076	P077	P078	P079	P080
TA1	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*LM t07*	*LM t07*	*LM t07*
TA2	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*LM t07*	*LM t07*	*LM t07*
TA3			*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*				
TA4	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*				
TA5	*RGT2 t62*																			
TA6	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*WM t23*	*WM t23*	*WM t23*	*WM t23*
TA7	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*				*WM t23*	*WM t23*	*WM t23*	*WM t23*

Figure 36. Third Month of Model Beta_min Detailed Schedule

Table 48. Model Input Files to Model Beta_min Detailed Schedule Comparison

Test Event	Test Asset Input	Actual Test Assets	Test Period Input	Actual Test Periods	Input Location	Actual Location	Successor	Successor Success?	Priority	Priority Issues
t01	1	1	1	1	ATC_MD	ATC	t02	Yes	high	
t02	1	1	3	3	ATC_MD	ATC			high	
t03	1	1	6	6	ATC_MD	ATC			high	
t04	1	1	3	3	ATC_MD	ATC			high	
t05	1	1	3	3	ATC_MD	ATC			high	
t06	1	1	3	3	ATC_MD	ATC			high	
t07	2	2	3	3	ATC_MD	ATC			medium	
t08	1	1	4	4	ATC_MD	ATC			high	
t09	1	1	14	14	ATC_MD	ATC			medium	
t10	1	1	3	3	ATC_MD	ATC			high	
t11	1	1	3	3	ATC_MD	ATC	t09	Yes	medium	performed before high tasks
t12	1	1	6	6	ATC_MD	ATC			high	
t13	3	3	13	13	AVTB_CA	AVTB	t14, t15, t16, t17, t18, t19, t20, t22, t23, t24, t63	Yes	high	
t14	1	1	7	7	AVTB_CA	AVTB			high	

Test Event	Test Asset Input	Actual Test Assets	Test Period Input	Actual Test Periods	Input Location	Actual Location	Successor	Successor Success?	Priority	Priority Issues
t15	1	1	3	3	AVTB_CA	AVTB	t16, t17, t18	Yes	high	
t16	1	1	3	3	AVTB_CA	AVTB			high	
t17	1	1	3	3	AVTB_CA	AVTB			high	
t18	1	1	3	3	AVTB_CA	AVTB			high	
t19	2	2	1	1	AVTB_CA	AVTB			high	
t20	1	1	1	1	AVTB_CA	AVTB			high	
t22	1	1	3	3	AVTB_CA	AVTB			high	
t23	2	2	4	4	AVTB_CA	AVTB			medium	
t24	1	1	4	4	AVTB_CA	AVTB			medium	
t25	4	4	13	13	ATC_MD		t01, t02, t03, t04, t05, t06, t07, t08, t09, t10, t11, t12, t14, t15, t16, t17, t18, t19, t20, t22, t23, t24, t27, t28, t29, t33, t36, t39 t40, t41, t53, t64	yes	high	
t27	1	1	1	1	ATC_MD	ATC			high	
t28	1	1	7	7	ATC_MD	ATC			high	
t29	1	1	7	7	ATC_MD	ATC			high	
t33	1	1	3	3	AVTB_CA	AVTB			high	

Test Event	Test Asset Input	Actual Test Assets	Test Period Input	Actual Test Periods	Input Location	Actual Location	Successor	Successor Success?	Priority	Priority Issues
t36	1	1	7	7	ATC_MD	ATC			high	
t37	1	1	7	7	AVTB_CA	AVTB			high	
t39	1	1	29	29	ATC_MD	ATC			medium	
t40	1	1	7	7	ATC_MD	ATC	t39	Yes	medium	performed before high tasks
t41	1	1	29	29	ATC_MD YPG_AZ	ATC			medium	
t53	1	1	21	21	WSMR_NM	WSMR	t22	Yes	medium	performed before high tasks
t56	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	AVTB			high	
t57	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	ATC			high	
t58	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	ATC			high	
t59	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	ATC			high	

Test Event	Test Asset Input	Actual Test Assets	Test Period Input	Actual Test Periods	Input Location	Actual Location	Successor	Successor Success?	Priority	Priority Issues
t60	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	ATC			medium	
t61	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	AVTB			medium	
t62	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	WSMR			medium	performed before high tasks probably due to venue
t63	1	1	21	21	AVTB_CA	AVTB			medium	
t64	1	1	15	15	ATC_MD	ATC			high	

Using the information provided in the Beta_min schedule and the comparison table, the verification assessment results for Beta_min schedule generated by the model is given in the Table 49 in the “Verification & Rationale” column, which is relative to Table 4 requirements that are repeated here.

Table 49. Model Controls and Constraints Beta_min Schedule Verification

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.0	Controls and Constraints	Not Applicable	Not Applicable	Not Applicable
2.1	Test Period (T=O)	The TE RSCSP model schedule shall be constrained by the test period.	The requirement shall be verified by confirming that the schedule is within the test period given in the test period input file.	MET Test period is 180 and model test period used is 66 days.
2.1.1	One Test Event on Test Asset during Time Period (T=O)	The TE RSCSP model shall not allow more than one test event during a time period on a test asset.	The requirement shall be verified by confirming that the schedule does not show more than one test event in a time period on a test asset.	PARTIALLY MET Output File does not assign a test asset, but in aggregate does not exceed the number of test assets.
2.1.2	Place all Test Events in Test Period (T=O)	The TE RSCSP model shall place all identified test events in a test period.	The requirement shall be verified by confirming that schedule places all identified test events in a test period.	MET Actual test events from input file are all placed in test periods.
2.1.3	Test Event Test Period Durations (T=O)	The TE RSCSP model shall use the test event test period durations input.	The requirement shall be verified by confirming that schedule test event test period durations matches the test events test period input file.	MET Actual test event test periods tracks to input tile.
2.2	Test Events (T=O)	The TE RSCSP model schedule shall be constrained by the test events.	The requirement shall be verified by confirming that the schedule includes all test events included in the test events input file.	MET Actual test events used track to input file.

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.3	Test Asset Type (O)	The TE RSCSP model shall use test asset type inputs.	The requirement shall be verified by confirming that schedule results places test events on the applicable test asset type based on the input file.	NOT VERIFIED Input files did not use more than one test asset type.
2.4	Test Venues (T=O)	The TE RSCSP model shall use test venues input.	The requirement shall be verified by confirming that the schedule includes only the test venues included in the test venues input file.	MET Actual test venues used track to input file.
2.5	Test Event Priorities	Not Applicable	Not Applicable	Not Applicable
2.5.1	Test Event Priority Relationships (T=O)	The TE RSCSP model shall be constrained by the test event priority relationships	The requirement shall be verified by confirming that schedule results are constrained by the test event priority relationships input file.	PARTIALLY MET In most cases, MET. There is an issue with t22, t40, and t53 medium test events happening before high priority tests.
2.5.2	High to Medium Priority Relationship (T=O)	The TE RSCSP model high priority test events shall be started before medium priority test events.	The requirement shall be verified by confirming that schedule starts high priority test events before medium priority test events.	PARTIALLY MET In most cases, MET. There is an issue with t22, t40, and t53 medium happening before high priority tests.
2.5.3	Medium to Low Priority Relationship (T=O)	The TE RSCSP model medium priority test events shall be started before low priority test events.	The requirement shall be verified by confirming that schedule starts medium priority test events before low priority test events.	NOT VERIFIED Model run did not include any low priority test events.
2.5.4	High to Low Priority Relationships (T=O)	The TE RSCSP model high priority test events shall be started before low priority test events.	The requirement shall be verified by confirming that schedule starts high priority test events before low priority test events.	NOT VERIFIED Model run did not include any low priority test events.
2.6	Test Venue Movement Test Periods (T=O)	The TE RSCSP model shall be constrained by the test venue movement test periods.	The requirement shall be verified by confirming that schedule uses the test venue movement test periods based on the input file.	MET Data shows that when moving venues, the input data matches the input file.

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.6.1	Add Time Period from Test Venue Movement (T=O)	The TE RSCSP model shall add time periods to the schedule based on the distance between test venues.	The requirement shall be verified by confirming that schedule results show that the time periods added to the schedule when the test asset moves to a new test venue are based on the input file.	MET Data shows that when moving venues, the input file test periods are added to the test schedule.
2.6.2	Schedule Test Event on Available Test Venues (T=O)	The TE RSCSP model shall not schedule a test event at a test venue that does not perform that test event.	The requirement shall be verified by confirming that schedule results show that the test events are scheduled only on available test venues based on the input file.	MET Test venues used track to test venues allowed based on the input file.
2.7	Test Venue Test Asset Capacity (T=O)	The TE RSCSP model shall be constrained by test venue test asset capacity input.	The requirement shall be verified by confirming that the number of test assets located at each test venue on the schedule does not exceed the capacity identified in the input file.	NOT VERIFIED The number of test assets assigned to a test venue by the model did not exceed the amount in the file, but the numbers in the file (10) did not really check the model.
2.8	Test Asset Test Venue Starting Location (T=O)	The TE RSCSP model shall be constrained by the test asset test venue starting location input.	The requirement shall be verified by confirming that schedule test assets start at the venues identified in the test asset test venue input file.	MET The starting locations and quantities (4 at ATC and 3 at AVTB) track to the input file.
2.9	Test Event Test Venue Relationships (T=O)	The TE RSCSP model shall be constrained by the test event test venue relationships input.	The requirement shall be verified by confirming that schedule test events are performed at the test venues identified in the test event test venue relationships input file.	MET Test events are assigned to allowed test venues based on the input file.
2.10	Test Event Precedence Relationships (T=O)	The TE RSCSP model shall be constrained by test event precedence relationships input.	The requirement shall be verified by confirming that schedule results are constrained by the test event precedence relationships input file.	MET Data shows that predecessor test events in the schedule occur before successor test events.

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.10.1	Test Event Predecessor First (T=O)	The TE RSCSP model shall perform predecessor test events prior to test event successor test events.	The requirement shall be verified by confirming that predecessor test events are on the schedule before successor test events regardless of test event priority.	MET Data shows that predecessor test events in the schedule occur before successor test events.
2.10.2	Test Event Successor Second (T=O)	The TE RSCSP model shall not perform successor test events prior to test event predecessor test events.	The requirement shall be verified by confirming that successor test events are on the schedule before predecessor test events regardless of test event priority.	MET Data shows that successor test events in the schedule occur after predecessor test events.
2.11	Number of Test Assets Needed for Test Events (T=O)	The TE RSCSP model shall use the number of test assets needed for test events input.	The requirement shall be verified by confirming that the schedule uses the number of test assets needed for test events input file.	MET Data shows that the number of test assets needed for a test event are used. For multi-vehicle operations, tests are performed simultaneously on the test assets.
2.12	Low Priority Schedule Relationship (O)	The TE RSCSP model low priority test events shall be allowed to go beyond the test period.	The requirement shall be verified by confirming that schedule results match the input file.	NOT VERIFIED Low priority test events are not used in this model run.
2.13	Test Asset Unavailability (O)	The TE RSCSP model shall be constrained by the test asset unavailability.	The requirement shall be verified by confirming that schedule places test assets only on available test assets based on the input file.	NOT VERIFIED Data for Test Asset Unavailability is not included in the model run.
2.14	Test Venue Unavailability (O)	The TE RSCSP model shall be constrained by test venue unavailability.	The requirement shall be verified by confirming that schedule results are constrained by the input file.	NOT VERIFIED Data for Test Venue Unavailability is not included in the model run.
2.15	Test Event Priority Deadlines (T=O)	The TE RSCSP model shall be constrained by the high and medium test event priority deadlines.	The requirement shall be verified by confirming that schedule results are constrained by the input file.	PARTIALLY MET This model run used 190 for the total test periods. High is 170, and medium is 190.

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.15.1	High Priority to Deadline Relationship (T=O)	The TE RSCSP model shall complete high priority test events before high priority deadlines.	The requirement shall be verified by confirming that schedule results start high priority test events before the high priority deadline.	MET This model run used 190 for the total test periods. High test periods is 170, and there are no high priority test events that go beyond this deadline. Schedule ends at test period 80.
2.15.2	Medium Priority to Deadline Relationship (T=O)	The TE RSCSP model shall complete medium priority test events before medium priority deadlines.	The requirement shall be verified by confirming that schedule results start medium priority test events before the medium priority deadline.	NOT VERIFIED This model run used 190 for the total test periods and the medium test periods, which means that it is not verified.
2.15.3	High Priority to Test Period Relationship (T=O)	The TE RSCSP model shall complete high priority test events before the test period completes.	The requirement shall be verified by confirming that schedule results complete high priority test events before the test period completes.	MET High priority test events end at 53. Schedule ends at test period 80. Test period ends at 190.
2.15.4	Medium Priority to Test Period Relationship (T=O)	The TE RSCSP model shall complete medium priority test events before the test period completes.	The requirement shall be verified by confirming that schedule results complete medium priority test events before the test period completes.	MET Medium priority test events end at test period 53. Schedule ends at test period 80. Test period ends at 190.

The results of the model controls and constraints requirements schedule verification assessment for Beta_min indicate that the majority of the threshold model controls and constraints requirements in Table 49 are MET, except for some that are PARTIALLY MET and some that are NOT VERIFIED. There are no controls and constraints requirements that are verified to be NOT MET.

Partially Met requirements. Data used for verification for time period, priority deadlines did not fully test the time period due to the values used. The following are considered to be PARTIALLY MET, and require an additional

verification event in order to be fully assessed: One Test Event on Test Asset during Time Period, Test Event Priority Relationships, High to Medium Priority Relationship, and Test Event Priority Deadlines.

Not Verified requirements. Data did not include low priority test events, test asset type, test venue capacity, test asset unavailability, test venue unavailability, and medium deadline. The following are considered to be NOT VERIFIED, and require an additional verification event in order to be assessed: Medium to Low Priority Relationship, High to Low Priority Relationships, Test Venue Test Asset Capacity, Test Asset Type Test Event Relationships, Test Asset Unavailability, Test Venue Unavailability, Medium Priority to Deadline Relationship, and Low Priority Schedule Relationship.

D. BETA_MODE SCHEDULE

	Time Period																			
Test Asset	P001	P002	P003	P004	P005	P006	P007	P008	P009	P010	P011	P012	P013	P014	P015	P016	P017	P018	P019	P020
TA1	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**LM t06**	**LM t06**
TA2	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t29**	**S/HF t29**
TA3	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**		**S/HF t36**
TA4	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**RGT1 t56**	**RGT1 t56**
TA5		**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	
TA6		**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**RGT1 t58**
TA7		**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**RGT1 t57**

Figure 37. First Month of Model Beta_mode Detailed Schedule

	Time Period																			
Test Asset	P021	P022	P023	P024	P025	P026	P027	P028	P029	P030	P031	P032	P033	P034	P035	P036	P037	P038	P039	P040
TA1	LM t06	LM t06	LM t01	LM t01	LM t12	LM t12	LM t12	LM t12	LM t12	LM t12	LM t12	LM t12	LM t05	LM t05	LM t05	LM t05	*LM t11*	*LM t11*	*LM t11*	*LM t11*
TA2	S/HF t29	S/HF t29	S/HF t29	S/HF t29	S/HF t29	S/HF t29	S/HF t29	S/HF t29		ATC to AVTB	ATC to AVTB	ATC to AVTB	ATC to AVTB	ATC to AVTB	ATC to AVTB	WM t15	WM t15	WM t15	WM t15	
TA3	S/HF t36	S/HF t36	S/HF t36	S/HF t36	S/HF t36	S/HF t36	S/HF t36	S/HF t36	S/HF t36	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	F t64
TA4	RGT1 t56	RGT1 t56	RGT1 t56	RGT1 t56	RGT1 t56	RGT1 t56	RGT1 t56	RGT1 t56	RGT1 t56	RGT1 t56	RGT1 t56	RGT1 t56	RGT1 t56	RGT1 t56	RGT1 t56	RGT1 t56	RGT1 t56	RGT1 t56	RGT1 t56	RGT1 t56
TA5	AVTB to WSMR	AVTB to WSMR	AVTB to WSMR	S t53	S t53	S t53	S t53	S t53	S t53	S t53	S t53	S t53	S t53	S t53	S t53	S t53	S t53	S t53	S t53	S t53
TA6	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58
TA7	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57	RGT1 t57

Figure 38. Second Month of Model Beta_mode Detailed Schedule

Time Period																				
Test Asset	P041	P042	P043	P044	P045	P046	P047	P048	P049	P050	P051	P052	P053	P054	P055	P056	P057	P058	P059	P060
TA1	**LM t10**	**LM t10**	**LM t10**	**LM t10**	**S/HF t27**	**S/HF t27**			**LM t02**	**LM t02**	**LM t02**	**LM t02**		**LM t08**	**LM t08**	**LM t08**	**LM t08**	**LM t08**	**LM t08**	*S/HF t39*
TA2	**S/HF t33**	**S/HF t33**	**S/HF t33**	**S/HF t33**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**
TA3	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**
TA4	**LM t04**	**LM t04**	**LM t04**	**LM t04**	**S/HF t28**	**S/HF t28**	**S/HF t28**	**S/HF t28**	**S/HF t28**	**S/HF t28**	**S/HF t28**	**S/HF t28**	**S/HF t28**	**S/HF t28**	**LM t03**	**LM t03**	**LM t03**	**LM t03**	**LM t03**	**LM t03**
TA5	S t53	S t53	S t53	S t53	S t53	S t53	S t53	S t53	S t53	S t53	S t53	S t53	S t53	WSM R to YPG	WSM R to YPG	WSM R to YPG	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*
TA6	**RGT1 t58**	**WM t16**	**WM t16**	**WM t16**	**WM t16**			**WM t14**	**WM t14**	**WM t14**	**WM t14**	**WM t14**	**WM t14**	**WM t14**	**WM t14**	**WM t14**	**WM t14**			**WM t19**
TA7	**RGT1 t57**	**WM t17**	**WM t17**	**WM t17**	**WM t17**	**S/HF t37**	**S/HF t37**	**S/HF t37**	**S/HF t37**	**S/HF t37**	**S/HF t37**	**S/HF t37**	**S/HF t37**	**S/HF t37**	**S/HF t37**		**WM t20**	**WM t20**		**WM t19**

Figure 39. Third Month of Model Beta_mode Detailed Schedule

Time Period																				
Test Asset	P061	P062	P063	P064	P065	P066	P067	P068	P069	P070	P071	P072	P073	P074	P075	P076	P077	P078	P079	P080
TA1	S/HF t39	S/HF t39	S/HF t39	S/HF t39	S/HF t39	S/HF t39	S/HF t39	S/HF t39	S/HF t39	S/HF t39	S/HF t39	S/HF t39	S/HF t39	S/HF t39	S/HF t39	S/HF t39	S/HF t39	S/HF t39	S/HF t39	S/HF t39
TA2	RGT1 t59	RGT1 t59	RGT1 t59	RGT1 t59	RGT1 t59	RGT1 t59	RGT2 t61	RGT2 t61	RGT2 t61	RGT2 t61	RGT2 t61	RGT2 t61	RGT2 t61	RGT2 t61	RGT2 t61	RGT2 t61	RGT2 t61	RGT2 t61	RGT2 t61	RGT2 t61
TA3	F t64																LM t07	LM t07	LM t07	LM t07
TA4	LM t03	LM t03															LM t07	LM t07	LM t07	LM t07
TA5	S/HF t41	S/HF t41	S/HF t41	S/HF t41	S/HF t41	S/HF t41	S/HF t41	S/HF t41	S/HF t41	S/HF t41	S/HF t41	S/HF t41	S/HF t41	S/HF t41	S/HF t41	S/HF t41	S/HF t41	S/HF t41	S/HF t41	S/HF t41
TA6	WM t19		WM t18	WM t18	WM t18	WM t18					C t63	C t63	C t63	C t63	C t63	C t63	C t63	C t63	C t63	C t63
TA7	WM t19		WM t22	WM t22	WM t22	WM t22	WM t24	WM t24	WM t24	WM t24	WM t24	WM t24	RGT2 t60	RGT2 t60	RGT2 t60	RGT2 t60	RGT2 t60	RGT2 t60	RGT2 t60	RGT2 t60

Figure 40. Fourth Month of Model Beta_mode Detailed Schedule

	Time Period																			
Test Asset	P081	P082	P083	P084	P085	P086	P087	P088	P089	P090	P091	P092	P093	P094	P095	P096	P097	P098	P099	P100
TA1	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	
TA2	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*									*WM t23*	*WM t23*	*WM t23*	*WM t23*
TA3			*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*
TA4	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*
TA5	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*				
TA6	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*
TA7	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*			*WM t23*	*WM t23*	*WM t23*	*WM t23*

Figure 41. Fifth Month of Model Beta_mode Detailed Schedule

Test Asset	P101	P102	P103	P104	P105	P106	P107	P108	P109	P110	P111	P112	P113	P114	P115	P116	P117	P118	P119	P120
	Time Period																			
TA1																				
TA2	*WM t23*	*WM t23*																		
TA3	*LM t09*	*LM t09*																		
TA4	*RGT2 t62*	*RGT2 t62*																		
TA5																				
TA6	*C t63*	*C t63*																		
TA7	*WM t23*	*WM t23*																		

Figure 42. Sixth Month of Model Beta_mode Detailed Schedule

Table 50. Model Input Files to Model Beta_mode Detailed Schedule Comparison

Test Event	Test Asset Input	Actual Test Assets	Test Period Input	Actual Test Periods	Input Location	Actual Location	Successor	Successor Success?	Priority	Priority Issues?
t01	1	1	2	2	ATC_MD	ATC	t02	yes	high	
t02	1	1	4	4	ATC_MD	ATC			high	
t03	1	1	8	8	ATC_MD	ATC			high	
t04	1	1	4	4	ATC_MD	ATC			high	
t05	1	1	4	4	ATC_MD	ATC			high	
t06	1	1	4	4	ATC_MD	ATC			high	
t07	2	2	4	4	ATC_MD	ATC			medium	
t08	1	1	6	6	ATC_MD	ATC			high	
t09	1	1	20	20	ATC_MD	ATC			medium	
t10	1	1	4	4	ATC_MD	ATC			high	
t11	1	1	4	4	ATC_MD	ATC	t09	yes	medium	performed before high tasks
t12	1	1	8	8	ATC_MD	ATC			high	
t13	3	3	18	18	AVTB_CA	AVTB	t14, t15, t16, t17, t18, t19, t20, t22, t23, t24, t63	yes	high	
t14	1	1	10	10	AVTB_CA	AVTB			high	
t15	1	1	4	4	AVTB_CA	AVTB	t16, t17, t18	yes	high	
t16	1	1	4	4	AVTB_CA	AVTB			high	
t17	1	1	4	4	AVTB_CA	AVTB			high	
t18	1	1	4	4	AVTB_CA	AVTB			high	
t19	2	1	2	2	AVTB_CA	AVTB			high	
t20	1	1	2	2	AVTB_CA	AVTB			high	
t22	1	1	4	4	AVTB_CA	AVTB			high	
t23	2	2	6	6	AVTB_CA	AVTB			medium	
t24	1	1	6	6	AVTB_CA	AVTB			medium	

Test Event	Test Asset Input	Actual Test Assets	Test Period Input	Actual Test Periods	Input Location	Actual Location	Successor	Successor Success?	Priority	Priority Issues?
t25	4	4	18	18	ATC_MD	ATC	t01, t02, t03, t04, t05, t06, t07, t08, t09, t10, t11, t12, t14, t15, t16, t17, t18, t19, t20, t22, t23, t24, t27, t28, t29, t33, t36, t39 t40, t41, t53, t64	yes	high	
t27	1	1	2	2	ATC_MD	ATC			high	
t28	1	1	10	10	ATC_MD	ATC			high	
t29	1	1	10	10	ATC_MD	ATC			high	
t33	1	1	4	4	AVTB_CA	AVTB			high	
t36	1	1	10	10	ATC_MD	ATC			high	
t37	1	1	10	10	AVTB_CA	AVTB			high	
t39	1	1	40	40	ATC_MD	ATC			medium	
t40	1	1	10	10	ATC_MD	ATC	t39		medium	performed before high tasks
t41	1	1	40	40	ATC_MD YPG_AZ	YPG			medium	
t53	1	1	30	30	WSMR_NM	WSMR	t22		medium	performed before high tasks
t56	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	ATC			high	
t57	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	AVTB			high	

Test Event	Test Asset Input	Actual Test Assets	Test Period Input	Actual Test Periods	Input Location	Actual Location	Successor	Successor Success?	Priority	Priority Issues?
t58	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	AVTB			high	
t59	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	AVTB			high	
t60	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	AVTB			medium	
t61	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	AVTB			medium	
t62	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	ATC			medium	
t63	1	1	32	32	AVTB_CA	AVTB			medium	
t64	1	1	22	22	ATC_MD	ATC			high	

Using the information provided in the Beta_mode schedule and the comparison table, the verification assessment results for Beta_mode schedule generated by the model is given in the Table 51 in the "Verification & Rationale" column, which is relative to Table 4 requirements that are repeated here.

Table 51. Model Controls and Constraints Beta_mode Schedule Verification

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.0	Controls and Constraints	Not Applicable	Not Applicable	Not Applicable
2.1	Test Period (T=O)	The TE RSCSP model schedule shall be constrained by the test period.	The requirement shall be verified by confirming that the schedule is within the test period given in the test period input file.	MET Test period is 180 and model test period used is 102 days.
2.1.1	One Test Event on Test Asset during Time Period (T=O)	The TE RSCSP model shall not allow more than one test event during a time period on a test asset.	The requirement shall be verified by confirming that the schedule does not show more than one test event in a time period on a test asset.	PARTIALLY MET Output File does not assign a test asset, but in aggregate does not exceed the number of test assets.
2.1.2	Place all Test Events in Test Period (T=O)	The TE RSCSP model shall place all identified test events in a test period.	The requirement shall be verified by confirming that schedule places all identified test events in a test period.	MET Actual test events from input file are all placed in test periods.
2.1.3	Test Event Test Period Durations (T=O)	The TE RSCSP model shall use the test event test period durations input.	The requirement shall be verified by confirming that schedule test event test period durations matches the test events test period input file.	MET Actual test event test periods tracks to input tile.
2.2	Test Events (T=O)	The TE RSCSP model schedule shall be constrained by the test events.	The requirement shall be verified by confirming that the schedule includes all test events included in the test events input file.	MET Actual test events used track to input file.

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.3	Test Asset Type (O)	The TE RSCSP model shall use test asset type inputs.	The requirement shall be verified by confirming that schedule results places test events on the applicable test asset type based on the input file.	NOT VERIFIED Input files did not use more than one test asset type.
2.4	Test Venues (T=O)	The TE RSCSP model shall use test venues input.	The requirement shall be verified by confirming that the schedule includes only the test venues included in the test venues input file.	MET Actual test venues used track to input file.
2.5	Test Event Priorities	Not Applicable	Not Applicable	Not Applicable
2.5.1	Test Event Priority Relationships (T=O)	The TE RSCSP model shall be constrained by the test event priority relationships	The requirement shall be verified by confirming that schedule results are constrained by the test event priority relationships input file.	PARTIALLY MET In most cases, MET. There is an issue with t11, and t40 medium test events happening before high priority tests.
2.5.2	High to Medium Priority Relationship (T=O)	The TE RSCSP model high priority test events shall be started before medium priority test events.	The requirement shall be verified by confirming that schedule starts high priority test events before medium priority test events.	PARTIALLY MET In most cases, MET. There is an issue with t11 and t40 medium happening before high priority tests.
2.5.3	Medium to Low Priority Relationship (T=O)	The TE RSCSP model medium priority test events shall be started before low priority test events.	The requirement shall be verified by confirming that schedule starts medium priority test events before low priority test events.	NOT VERIFIED Model run did not include any low priority test events.
2.5.4	High to Low Priority Relationships (T=O)	The TE RSCSP model high priority test events shall be started before low priority test events.	The requirement shall be verified by confirming that schedule starts high priority test events before low priority test events.	NOT VERIFIED Model run did not include any low priority test events.
2.6	Test Venue Movement Test Periods (T=O)	The TE RSCSP model shall be constrained by the test venue movement test periods.	The requirement shall be verified by confirming that schedule uses the test venue movement test periods based on the input file.	MET Data shows that when moving venues, the input data matches the input file.

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.6.1	Add Time Period from Test Venue Movement (T=O)	The TE RSCSP model shall add time periods to the schedule based on the distance between test venues.	The requirement shall be verified by confirming that schedule results show that the time periods added to the schedule when the test asset moves to a new test venue are based on the input file.	MET Data shows that when moving venues, the input file test periods are added to the test schedule.
2.6.2	Schedule Test Event on Available Test Venues (T=O)	The TE RSCSP model shall not schedule a test event at a test venue that does not perform that test event.	The requirement shall be verified by confirming that schedule results show that the test events are scheduled only on available test venues based on the input file.	MET Test venues used track to test venues allowed based on the input file.
2.7	Test Venue Test Asset Capacity (T=O)	The TE RSCSP model shall be constrained by test venue test asset capacity input.	The requirement shall be verified by confirming that the number of test assets located at each test venue on the schedule does not exceed the capacity identified in the input file.	NOT VERIFIED The number of test assets assigned to a test venue by the model did not exceed the amount in the file, but the numbers in the file (10) did not really check the model.
2.8	Test Asset Test Venue Starting Location (T=O)	The TE RSCSP model shall be constrained by the test asset test venue starting location input.	The requirement shall be verified by confirming that schedule test assets start at the venues identified in the test asset test venue input file.	MET The starting locations and quantities (4 at ATC and 3 at AVTB) track to the input file.
2.9	Test Event Test Venue Relationships (T=O)	The TE RSCSP model shall be constrained by the test event test venue relationships input.	The requirement shall be verified by confirming that schedule test events are performed at the test venues identified in the test event test venue relationships input file.	MET Test events are assigned to allowed test venues based on the input file.
2.10	Test Event Precedence Relationships (T=O)	The TE RSCSP model shall be constrained by test event precedence relationships input.	The requirement shall be verified by confirming that schedule results are constrained by the test event precedence relationships input file.	MET Data shows that predecessor test events in the schedule occur before successor test events.

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.10.1	Test Event Predecessor First (T=O)	The TE RSCSP model shall perform predecessor test events prior to test event successor test events.	The requirement shall be verified by confirming that predecessor test events are on the schedule before successor test events regardless of test event priority.	MET Data shows that predecessor test events in the schedule occur before successor test events.
2.10.2	Test Event Successor Second (T=O)	The TE RSCSP model shall not perform successor test events prior to test event predecessor test events.	The requirement shall be verified by confirming that successor test events are on the schedule before predecessor test events regardless of test event priority.	MET Data shows that successor test events in the schedule occur after predecessor test events.
2.11	Number of Test Assets Needed for Test Events (T=O)	The TE RSCSP model shall use the number of test assets needed for test events input.	The requirement shall be verified by confirming that the schedule uses the number of test assets needed for test events input file.	MET Data shows that the number of test assets needed for a test event are used. For multi-vehicle operations, tests are performed simultaneously on the test assets.
2.12	Low Priority Schedule Relationship (O)	The TE RSCSP model low priority test events shall be allowed to go beyond the test period.	The requirement shall be verified by confirming that schedule results match the input file.	NOT VERIFIED Low priority test events are not used in this model run.
2.13	Test Asset Unavailability (O)	The TE RSCSP model shall be constrained by the test asset unavailability.	The requirement shall be verified by confirming that schedule places test assets only on available test assets based on the input file.	NOT VERIFIED Data for Test Asset Unavailability is not included in the model run.
2.14	Test Venue Unavailability (O)	The TE RSCSP model shall be constrained by test venue unavailability.	The requirement shall be verified by confirming that schedule results are constrained by the input file.	NOT VERIFIED Data for Test Venue Unavailability is not included in the model run.
2.15	Test Event Priority Deadlines (T=O)	The TE RSCSP model shall be constrained by the high and medium test event priority deadlines.	The requirement shall be verified by confirming that schedule results are constrained by the input file.	PARTIALLY MET This model run used 190 for the total test periods. High is 170, and medium is 190.

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.15.1	High Priority to Deadline Relationship (T=O)	The TE RSCSP model shall complete high priority test events before high priority deadlines.	The requirement shall be verified by confirming that schedule results start high priority test events before the high priority deadline.	MET
2.15.2	Medium Priority to Deadline Relationship (T=O)	The TE RSCSP model shall complete medium priority test events before medium priority deadlines.	The requirement shall be verified by confirming that schedule results start medium priority test events before the medium priority deadline.	NOT VERIFIED This model run used 190 for the total test periods and the medium test periods, which means that it is not verified.
2.15.3	High Priority to Test Period Relationship (T=O)	The TE RSCSP model shall complete high priority test events before the test period completes.	The requirement shall be verified by confirming that schedule results complete high priority test events before the test period completes.	MET High priority test events end at 66. Schedule ends at test period 102. Test period ends at 190.
2.15.4	Medium Priority to Test Period Relationship (T=O)	The TE RSCSP model shall complete medium priority test events before the test period completes.	The requirement shall be verified by confirming that schedule results complete medium priority test events before the test period completes.	MET Medium priority test events end at test period 102. Schedule ends at test period 102 Test period ends at 190.

The results of the model controls and constraints requirements schedule verification assessment for Beta_mode indicate that the majority of the threshold model controls and constraints requirements in Table 51 are MET, except for some that are PARTIALLY MET and some that are NOT VERIFIED. There are no controls and constraints requirements that are verified to be NOT MET.

Partially Met requirements. Data used for verification for time period, priority deadlines did not fully test the time period due to the values used. The following are considered to be PARTIALLY MET, and require an additional verification event in order to be fully assessed: One Test Event on Test Asset during Time Period, Test Event Priority Relationships, High to Medium Priority Relationship, and Test Event Priority Deadlines.

Not Verified requirements. Data did not include low priority test events, test asset type, test venue capacity, test asset unavailability, test venue unavailability, and medium deadline. The following are considered to be NOT VERIFIED, and require an additional verification event in order to be assessed: Medium to Low Priority Relationship, High to Low Priority Relationships, Test Venue Test Asset Capacity, Test Asset Type Test Event Relationships, Test Asset Unavailability, Test Venue Unavailability, Medium Priority to Deadline Relationship, and Low Priority Schedule Relationship.

E. BETA_MEAN SCHEDULE

	Time Period																			
Test Asset	P001	P002	P003	P004	P005	P006	P007	P008	P009	P010	P011	P012	P013	P014	P015	P016	P017	P018	P019	P020
TA1	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**
TA2	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**
TA3	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**
TA4	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**	**S/HF t25**
TA5		**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**
TA6		**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**
TA7		**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**	**S/HF t13**

Figure 43. First Month of Model Beta_mean Detailed Schedule

Test Asset	Time Period																			
	P021	P022	P023	P024	P025	P026	P027	P028	P029	P030	P031	P032	P033	P034	P035	P036	P037	P038	P039	P040
TA1		**LM t08**	**LM t08**	**LM t08**	**LM t08**	**LM t08**	**LM t08**	**LM t08**	**LM t12**	**LM t12**	**LM t12**	**LM t12**	**LM t12**	**LM t12**	**LM t12**	**LM t12**	**LM t12**	**LM t03**	**LM t03**	**LM t03**
TA2	**S/HF t27**	**S/HF t27**	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	*S/HF t40*	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**	**F t64**
TA3	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**	**RGT1 t57**
TA4		**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**	**RGT1 t59**
TA5	**S/HF t13**		AVTB to WSMR	AVTB to WSMR	AVTB to WSMR	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*	*S t53*
TA6	**S/HF t13**						**S/HF t33**	**S/HF t33**	**S/HF t33**	**S/HF t33**	**S/HF t33**		**WM t15**	**WM t15**	**WM t15**	**WM t15**	**WM t15**	**WM t20**	**WM t20**	**WM t18**
TA7	**S/HF t13**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**	**RGT1 t56**

Figure 44. Second Month of Model Beta_mean Detailed Schedule

	Time Period																			
Test Asset	P041	P042	P043	P044	P045	P046	P047	P048	P049	P050	P051	P052	P053	P054	P055	P056	P057	P058	P059	P060
TA1	LM t03	LM t03	LM t03	LM t03	LM t03	LM t03	LM t01	LM t01	LM t10	LM t10	LM t10	LM t10	LM t10	S/HF t36	S/HF t36	S/HF t36	S/HF t36	S/HF t36	S/HF t36	S/HF t36
TA2	F t64	F t64	F t64	F t64	F t64	F t64	F t64	F t64	F t64	F t64	F t64	F t64	F t64	F t64	F t64	F t64		S/HF t28	S/HF t28	S/HF t28
TA3	RGT1 t57	RGT1 t57	LM t06	LM t06	LM t06	LM t06	LM t06	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58	RGT1 t58
TA4	RGT1 t59	RGT1 t59	RGT1 t59	*LM* *t11*	*LM* *t11*	*LM* *t11*	*LM* *t11*	*LM* *t11*	S/HF t29	S/HF t29	S/HF t29	S/HF t29	S/HF t29	S/HF t29	S/HF t29	S/HF t29	S/HF t29	S/HF t29	S/HF t29	S/HF t05
TA5	*S* *t53*	*S* *t53*	*S* *t53*	*S* *t53*	*S* *t53*	*S* *t53*	*S* *t53*	*S* *t53*	*S* *t53*	*S* *t53*	*S* *t53*	*S* *t53*	*S* *t53*	*S* *t53*	*S* *t53*	*S* *t53*	*S* *t53*	WSMR to YPG	WSMR to YPG	WSMR to YPG
TA6	WM t18	WM t18	WM t18	WM t18					WM t14	WM t14	WM t14	WM t14	WM t14	WM t14	WM t14	WM t14	WM t14	WM t14	WM t14	WM t16
TA7	RGT1 t56	RGT1 t56	RGT1 t56	WM t17	WM t17	WM t17	WM t17	WM t17	S/HF t37	S/HF t37	S/HF t37	S/HF t37	S/HF t37	S/HF t37	S/HF t37	S/HF t37	S/HF t37	S/HF t37	S/HF t37	

Figure 45. Third Month of Model Beta_mean Detailed Schedule

	Time Period																			
Test Asset	P061	P062	P063	P064	P065	P066	P067	P068	P069	P070	P071	P072	P073	P074	P075	P076	P077	P078	P079	P080
TA1	**S/HF t36**	**S/HF t36**	**S/HF t36**	**S/HF t36**	**LM t02**	**LM t02**	**LM t02**	**LM t02**	**LM t02**	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*
TA2	**S/HF t28**	**S/HF t28**	**S/HF t28**	**S/HF t28**	**S/HF t28**	**S/HF t28**	**S/HF t28**	**S/HF t28**	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*
TA3	**RGT 1 t58**	**RGT 1 t58**	**RGT 1 t58**	**RGT 1 t58**	**RGT 1 t58**	**RGT 1 t58**	**RGT 1 t58**	**RGT 1 t58**	**RGT 1 t58**	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*
TA4	**S/HF t05**	**S/HF t05**	**S/HF t05**	**S/HF t05**	**LM t04**	**LM t04**	**LM t04**	**LM t04**	**LM t04**								*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*
TA5	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*
TA6	**WM t16**	**WM t16**	**WM t16**	**WM t16**			*WM t23*	*WM t23*	*WM t23*	*WM t23*	*WM t23*	*WM t23*	*WM t23*	*WM t23*	*WM t24*	*WM t24*	*WM t24*	*WM t24*	*WM t24*	*WM t24*
TA7		**WM t22**	**WM t22**	**WM t22**	**WM t22**	**WM t22**	*WM t23*	*WM t23*	*WM t23*	*WM t23*	*WM t23*	*WM t23*	*WM t23*	*WM t23*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*

Figure 46. Fourth Month of Model Beta_mean Detailed Schedule

	Time Period																			
Test Asset	P081	P082	P083	P084	P085	P086	P087	P088	P089	P090	P091	P092	P093	P094	P095	P096	P097	P098	P099	P100
TA1	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*	*LM t09*			*LM t07*	*LM t07*	*LM t07*	*LM t07*	*LM t07*		
TA2	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*
TA3	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*	*RGT2 t61*			*LM t07*	*LM t07*	*LM t07*	*LM t07*	*LM t07*		
TA4	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*	*RGT2 t62*		
TA5	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*	*S/HF t41*
TA6	*WM t24*				*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT 2 t60*	*RGT 2 t60*
TA7	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*

Figure 47. Fifth Month of Model Beta_mean Detailed Schedule

Test Asset	P101	P102	P103	P104	P105	P106	P107	P108	P109	P110	P111	P112	P113	P114	P115	P116	P117	P118	P119	P120
TA1																				
TA2	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*	*S/HF t39*									
TA3																				
TA4																				
TA5	*S/HF t41*	*S/HF t41*	*S/HF t41*																	
TA6	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*	*RGT2 t60*		**WM t19**	**WM t19**											
TA7	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	*C t63*	**WM t19**	**WM t19**											

Time Period

Figure 48. Sixth Month of Model Beta_mean Detailed Schedule

Table 52. Model Input Files to Model Beta_mean Detailed Schedule Comparison

Test Event	Test Asset Input	Actual Test Assets	Test Period Av Calc	Actual Beta Test Periods	Input Location	Actual Location	Successor	Successor Success?	Priority	Priority Issues?
t01	1	1	2	2	ATC_MD	ATC	t02	yes	high	
t02	1	1	4	5	ATC_MD	ATC			high	
t03	1	1	8	9	ATC_MD	ATC			high	
t04	1	1	4	5	ATC_MD	ATC			high	
t05	1	1	4	5	ATC_MD	ATC			high	
t06	1	1	4	5	ATC_MD	ATC			high	
t07	2	2	4	5	ATC_MD	ATC			medium	
t08	1	1	6	7	ATC_MD	ATC			high	
t09	1	1	20	22	ATC_MD	ATC			medium	
t10	1	1	4	5	ATC_MD	ATC			high	
t11	1	1	4	5	ATC_MD	ATC	t09	yes	medium	performed before high tasks
t12	1	1	8	9	ATC_MD	ATC			high	
t13	3	3	18	20	AVTB_CA	AVTB	t14, t15, t16, t17, t18, t19, t20, t22, t23, t24, t63	yes	high	
t14	1	1	10	11	AVTB_CA	AVTB			high	
t15	1	1	4	5	AVTB_CA	AVTB	t16, t17, t18	yes	high	
t16	1	1	4	5	AVTB_CA	AVTB			high	
t17	1	1	4	5	AVTB_CA	AVTB			high	
t18	1	1	4	5	AVTB_CA	AVTB			high	
t19	2	2	2	2	AVTB_CA	AVTB			high	Performe d at end after low priority tasks
t20	1	1	2	2	AVTB_CA	AVTB			high	
t22	1	1	4	5	AVTB_CA	AVTB			high	
t23	2	2	6	8	AVTB_CA	AVTB			medium	
t24	1	1	6	7	AVTB_CA	AVTB			medium	

Test Event	Test Asset Input	Actual Test Assets	Test Period Av Calc	Actual Beta Test Periods	Input Location	Actual Location	Successor	Successor Success?	Priority	Priority Issues?
t25	4	4	18	20	ATC_MD	ATC	t01, t02, t03, t04, t05, t06, t07, t08, t09, t10, t11, t12, t14, t15, t16, t17, t18, t19, t20, t22, t23, t24, t27, t28, t29, t33, t36, t39 t40, t41, t53, t64	yes	high	
t27	1	1	2	2	ATC_MD	ATC			high	
t28	1	1	10	11	ATC_MD	ATC			high	
t29	1	1	10	11	ATC_MD	ATC			high	
t33	1	1	4	5	AVTB_CA	AVTB			high	
t36	1	1	10	11	ATC_MD	ATC			high	
t37	1	1	10	11	AVTB_CA	AVTB			high	
t39	1	1	40	43	ATC_MD	ATC			medium	
t40	1	1	10	10	ATC_MD	ATC	t39	yes	medium	performed before high tasks
t41	1	1	40	43	ATC_MD YPG_AZ	YPG			medium	
t53	1	1	30	32	WSMR_NM	WSMR	t22	yes	medium	performed before high tasks
t56	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	AVTB			high	
t57	1	1	22	22	ATC_MD	t57	1	1	22	22

Test Event	Test Asset Input	Actual Test Assets	Test Period Av Calc	Actual Beta Test Periods	Input Location	Actual Location	Successor	Successor Success?	Priority	Priority Issues?
t58	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	ATC			high	
t59	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	ATC			high	
t60	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	AVTB			medium	
t61	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	ATC			medium	
t62	1	1	22	22	ATC_MD AVTB_CA WSMR_NM YPG_AZ	ATC			medium	
t63	1	1	32	33	AVTB_CA	AVTB			medium	
t64	1	1	22	23	ATC_MD	ATC			high	

Using the information provided in the Beta_mean schedule and the comparison table, the verification assessment results for Beta_mean schedule generated by the model is given in the Table 53 in the "Verification & Rationale" column, which is relative to Table 4 requirements that are repeated here

Table 53. Model Controls and Constraints Beta_mean Schedule Verification

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.0	Controls and Constraints	Not Applicable	Not Applicable	Not Applicable
2.1	Test Period (T=O)	The TE RSCSP model schedule shall be constrained by the test period.	The requirement shall be verified by confirming that the schedule is within the test period given in the test period input file.	MET Test period is 180 and model test period used is 111 days.
2.1.1	One Test Event on Test Asset during Time Period (T=O)	The TE RSCSP model shall not allow more than one test event during a time period on a test asset.	The requirement shall be verified by confirming that the schedule does not show more than one test event in a time period on a test asset.	PARTIALLY MET Output File does not assign a test asset, but in aggregate does not exceed the number of test assets.
2.1.2	Place all Test Events in Test Period (T=O)	The TE RSCSP model shall place all identified test events in a test period.	The requirement shall be verified by confirming that schedule places all identified test events in a test period.	MET Actual test events from input file are all placed in test periods.
2.1.3	Test Event Test Period Durations (T=O)	The TE RSCSP model shall use the test event test period durations input.	The requirement shall be verified by confirming that schedule test event test period durations matches the test events test period input file.	MET Actual test event test periods tracks to input tile.
2.2	Test Events (T=O)	The TE RSCSP model schedule shall be constrained by the test events.	The requirement shall be verified by confirming that the schedule includes all test events included in the test events input file.	MET Actual test events used track to input file.
2.3	Test Asset Type (O)	The TE RSCSP model shall use test asset type inputs.	The requirement shall be verified by confirming that schedule results places test events on the applicable test asset type based on the input file.	NOT VERIFIED Input files did not use more than one test asset type.

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.4	Test Venues (T=O)	The TE RSCSP model shall use test venues input.	The requirement shall be verified by confirming that the schedule includes only the test venues included in the test venues input file.	MET Actual test venues used track to input file.
2.5	Test Event Priorities	Not Applicable	Not Applicable	Not Applicable
2.5.1	Test Event Priority Relationships (T=O)	The TE RSCSP model shall be constrained by the test event priority relationships	The requirement shall be verified by confirming that schedule results are constrained by the test event priority relationships input file.	PARTIALLY MET In most cases, MET. There is an issue with t11, t40, and t53 medium test events happening before high priority tests.
2.5.2	High to Medium Priority Relationship (T=O)	The TE RSCSP model high priority test events shall be started before medium priority test events.	The requirement shall be verified by confirming that schedule starts high priority test events before medium priority test events.	PARTIALLY MET In most cases, MET. There is an issue with t11, t40, and t53 medium happening before high priority tests.
2.5.3	Medium to Low Priority Relationship (T=O)	The TE RSCSP model medium priority test events shall be started before low priority test events.	The requirement shall be verified by confirming that schedule starts medium priority test events before low priority test events.	NOT VERIFIED Model run did not include any low priority test events.
2.5.4	High to Low Priority Relationships (T=O)	The TE RSCSP model high priority test events shall be started before low priority test events.	The requirement shall be verified by confirming that schedule starts high priority test events before low priority test events.	NOT VERIFIED Model run did not include any low priority test events.
2.6	Test Venue Movement Test Periods (T=O)	The TE RSCSP model shall be constrained by the test venue movement test periods.	The requirement shall be verified by confirming that schedule uses the test venue movement test periods based on the input file.	MET Data shows that when moving venues, the input data matches the input file.

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.6.1	Add Time Period from Test Venue Movement (T=O)	The TE RSCSP model shall add time periods to the schedule based on the distance between test venues.	The requirement shall be verified by confirming that schedule results show that the time periods added to the schedule when the test asset moves to a new test venue are based on the input file.	MET Data shows that when moving venues, the input file test periods are added to the test schedule.
2.6.2	Schedule Test Event on Available Test Venues (T=O)	The TE RSCSP model shall not schedule a test event at a test venue that does not perform that test event.	The requirement shall be verified by confirming that schedule results show that the test events are scheduled only on available test venues based on the input file.	MET Test venues used track to test venues allowed based on the input file.
2.7	Test Venue Test Asset Capacity (T=O)	The TE RSCSP model shall be constrained by test venue test asset capacity input.	The requirement shall be verified by confirming that the number of test assets located at each test venue on the schedule does not exceed the capacity identified in the input file.	NOT VERIFIED The number of test assets assigned to a test venue by the model did not exceed the amount in the file, but the numbers in the file (10) did not really check the model.
2.8	Test Asset Test Venue Starting Location (T=O)	The TE RSCSP model shall be constrained by the test asset test venue starting location input.	The requirement shall be verified by confirming that schedule test assets start at the venues identified in the test asset test venue input file.	MET The starting locations and quantities (4 at ATC and 3 at AVTB) track to the input file.
2.9	Test Event Test Venue Relationships (T=O)	The TE RSCSP model shall be constrained by the test event test venue relationships input.	The requirement shall be verified by confirming that schedule test events are performed at the test venues identified in the test event test venue relationships input file.	MET Test events are assigned to allowed test venues based on the input file.
2.10	Test Event Precedence Relationships (T=O)	The TE RSCSP model shall be constrained by test event precedence relationships input.	The requirement shall be verified by confirming that schedule results are constrained by the test event precedence relationships input file.	MET Data shows that predecessor test events in the schedule occur before successor test events.

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.10.1	Test Event Predecessor First (T=O)	The TE RSCSP model shall perform predecessor test events prior to test event successor test events.	The requirement shall be verified by confirming that predecessor test events are on the schedule before successor test events regardless of test event priority.	MET Data shows that predecessor test events in the schedule occur before successor test events.
2.10.2	Test Event Successor Second (T=O)	The TE RSCSP model shall not perform successor test events prior to test event predecessor test events.	The requirement shall be verified by confirming that successor test events are on the schedule before predecessor test events regardless of test event priority.	MET Data shows that successor test events in the schedule occur after predecessor test events.
2.11	Number of Test Assets Needed for Test Events (T=O)	The TE RSCSP model shall use the number of test assets needed for test events input.	The requirement shall be verified by confirming that the schedule uses the number of test assets needed for test events input file.	MET Data shows that the number of test assets needed for a test event are used. For multi-vehicle operations, tests are performed simultaneously on the test assets.
2.12	Low Priority Schedule Relationship (O)	The TE RSCSP model low priority test events shall be allowed to go beyond the test period.	The requirement shall be verified by confirming that schedule results match the input file.	NOT VERIFIED Low priority test events are not used in this model run.
2.13	Test Asset Unavailability (O)	The TE RSCSP model shall be constrained by the test asset unavailability.	The requirement shall be verified by confirming that schedule places test assets only on available test assets based on the input file.	NOT VERIFIED Data for Test Asset Unavailability is not included in the model run.
2.14	Test Venue Unavailability (O)	The TE RSCSP model shall be constrained by test venue unavailability.	The requirement shall be verified by confirming that schedule results are constrained by the input file.	NOT VERIFIED Data for Test Venue Unavailability is not included in the model run.
2.15	Test Event Priority Deadlines (T=O)	The TE RSCSP model shall be constrained by the high and medium test event priority deadlines.	The requirement shall be verified by confirming that schedule results are constrained by the input file.	PARTIALLY MET This model run used 190 for the total test periods. High is 170, and medium is 190.

Para #	Para Title	Requirement	Verification Criteria	Verification & Rationale
2.15.1	High Priority to Deadline Relationship (T=O)	The TE RSCSP model shall complete high priority test events before high priority deadlines.	The requirement shall be verified by confirming that schedule results start high priority test events before the high priority deadline.	MET
2.15.2	Medium Priority to Deadline Relationship (T=O)	The TE RSCSP model shall complete medium priority test events before medium priority deadlines.	The requirement shall be verified by confirming that schedule results start medium priority test events before the medium priority deadline.	NOT VERIFIED This model run used 190 for the total test periods and the medium test periods, which means that it is not verified.
2.15.3	High Priority to Test Period Relationship (T=O)	The TE RSCSP model shall complete high priority test events before the test period completes.	The requirement shall be verified by confirming that schedule results complete high priority test events before the test period completes.	MET High priority test events end at 109. Schedule ends at test period 111. Test period ends at 190. Test event t19, which requires two vehicles, is put at the end.
2.15.4	Medium Priority to Test Period Relationship (T=O)	The TE RSCSP model shall complete medium priority test events before the test period completes.	The requirement shall be verified by confirming that schedule results complete medium priority test events before the test period completes.	MET Medium priority test events end at test period 111. Schedule ends at test period 111. Test period ends at 190.

The results of the model controls and constraints requirements schedule verification assessment indicate that the majority of the threshold model controls and constraints requirements in Table 53 are MET, except for some that are PARTIALLY MET and some that are NOT VERIFIED. There are no controls and constraints requirements that are verified to be NOT MET.

Partially Met requirements. Data used for verification for time period, priority deadlines did not fully test the time period due to the values used. The

following are considered to be PARTIALLY MET, and require an additional verification event in order to be fully assessed: One Test Event on Test Asset during Time Period, Test Event Priority Relationships, High Priority to Test Period Relationship, High to Medium Priority Relationship, and Test Event Priority Deadlines.

Not Verified requirements. Data did not include low priority test events, test asset type, test venue capacity, test asset unavailability, test venue unavailability, and medium deadline. The following are considered to be NOT VERIFIED, and require an additional verification event in order to be assessed: Medium to Low Priority Relationship, High to Low Priority Relationships, Test Venue Test Asset Capacity, Test Asset Type Test Event Relationships, Test Asset Unavailability, Test Venue Unavailability, Medium Priority to Deadline Relationship, and Low Priority Schedule Relationship.

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